AGRICULTURAL PARASITOLOGY: AN INTRODUCTION

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AN INTRODUCTION

BY

C. L. WALTON, M.Sc., PH.D. (WALES)

AND

W. REES WRIGHT, M.Sc. (WALES)

UNIVERSITY COLLEGE OF NORTH WALES, BANGOR

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"A knowledge of the properties, economy, propagation, and, in short, of the life and conversation of these animals, is a necessary step to lead us to some method of preventing their depredations."—GILBERT WHITE. "The Natural History of Selborne." Letter xxxiv. 1771.

"The aim of Parasitology, regarded as a pure science, is to observe . . . numerous and precise facts, to co-ordinate them, and to study their bearings, so that we may formulate biological laws which shall be as general as is possible.

"But alongside of this theoretical end, Parasitology pursues especially a practical end, which is the destruction of parasites, either in the host, or in the external medium. This end can be obtained when the biology of the parasite is known . . .

"The biological problem passes into the economic, and it is for man to decide if the expenditure involved in the contest with the parasites is compensated by the advantages which he will draw from it"—E. BRUMPT. "Précis de Parasitologie," p. 3. 1922.

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PREFACE

DURING twelve years' experience of teaching Agricultural Zoology to students of all grades, the senior author of this book has throughout felt the want of a short and concise account of the parasites affecting the British stock-breeder. This want has also been voiced by numerous students during the process of these courses. Other and more elaborate volumes exist, but are more technical than is required for the purpose, or only contain part of the information needed, whilst a considerable range of specialist literature must be consulted to cover the subject. This attempt to fill the gap indicated has been arranged largely along the lines taken by the course of lectures given each winter at Bangor by the senior author, and an effort has been made to combine biological principles and practical application in a concise form. It has been thought advisable to restrict the scope of this book for the most part to the more important parasites of farm live stock in the British Isles, although short mention has been made from time to time of others, and to conditions abroad, where such seemed called for in order to give perspective or force to a statement.

Terms which it is considered should be known by students and others are italicised at their first mention, and explained, for the most part, without reference to a glossary. References to literature are given in some detail at the ends of the chapters, since we consider it

important that students and others should, if they so wish, refer to the greater detail which they may find by so doing.

It is realised that what is here attempted must fall short in many ways, but will have served a useful purpose should it prove a stimulus to the further study of an undoubtedly important subject.

The writers are greatly indebted to Professor Warrington Yorke, Professor W. S. Patton, Dr. T. Southwell, and Dr. L. E. Robinson for helpful criticism and advice in connection with various portions of the book, and to Professor G. H. F. Nuttall, F.R.S., for the loan of the blocks for Plate III, dealing with *Ixodes*, and for text-figure 1. Dr. R. Alun Roberts has kindly read over certain chapters.

Except where otherwise stated, the illustrations are the work of the junior author. The editors of *Annals of Tropical Medicine and Parasitology* have permitted us to include figures from a paper by the junior writer in Plate II.

C. L. W.
W. R. W.

DEPARTMENT OF AGRICULTURE,
UNIVERSITY COLLEGE,
BANGOR.
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TABLE OF CONTENTS

LIST OF PLATES

FIGURES IN THE TEXT

THE measurements in this book have been given in the Metric system. For the convenience of those who are not acquainted with it, the following approximate equivalents in "Imperial" measure are given.

1 centimetre (cm.) = 10 millimetres = $\frac{4}{10}$ inch.
1 millimetre (mm.) = $\frac{1}{25}$ inch.
1 mm. = 1,000 micra (μ). 1 μ = $\frac{1}{25000}$ inch.

AGRICULTURAL PARASITOLOGY

CHAPTER I

PARASITOLOGY

THE word "*Parasitology*" denotes the scientific study of parasites, and parasites may be defined as "organisms which take up their abode, temporarily or permanently, within or upon other organisms in order to feed upon them or to share their food, and which are more or less specialised for that purpose." This definition is adapted from the well-known book by M. Braun (1), a noted *parasitologist*, which is the term used for one who studies parasites. Brumpt (2), another distinguished student of these forms of life, had defined parasites as "living beings . . . which spend a part or the whole of their life in a state of dependence upon other living organisms." Care should be taken not to confuse parasitism with the predatory habit.

It must not be assumed, however, that whenever two or more kinds of animals are found dwelling in close association that we are dealing with a case of *parasitism*, as certain other conditions exist which require explanation here since they are in all probability the forerunners of the *parasitic* habit. One of these conditions is known as *commensalism*, and is defined as "one organism

living with another and sharing the food, both species as a rule benefiting by the association" (3). Cases of this kind do exist, but it is obvious that any partnership is liable to become one-sided and to be more to the benefit of one than the other; and also, that it is but a short and logical step for such relationships to be more or less pronounced. Animal relationships of this type probably begin in a quite loose and simple manner, gradually becoming more and more habitual and intimate until they may be regarded as normal to the creatures in question.

Symbiosis, again, is a condition in which two animals, two plants, or plant and animal, live in mutually beneficent partnership. Each partner in such a partnership is known as a *symbiont*. Well-known and well-marked cases exist, more especially among plants, in which the partnership is of the highest importance to the participants, and the bond in such cases may be regarded as almost indissoluble. Such associations may commence loosely and result in the relationships just defined, or may pass directly or gradually into a condition of actual *parasitisation*. The original relation is that of a smaller free-living creature attracted to a larger, by either spare food, waste products from life processes, or shelter or foothold afforded by body form. The larger creature may either benefit by or tolerate such an arrangement, or be unable to prevent it, or to rid itself of its lodger or visitor. In due course the linkage becomes stronger, and may become essential to one individual (now a *parasite*) and detrimental to the *host*, as the parasitised individual is termed. The relation of parasite to host is both interesting and varied. The host may remain unharmed, and little if at all inconvenienced, or may, on the other hand, be affected in the most serious manner. The parasite also may show but little alteration from the normal, or may become so adapted to the host as to

become very greatly modified. Certain of these modifications are common to the majority of parasites and include loss of motility, a tendency to flattening, a loss of sense organs and of any other organs no longer of value in a different environment. Another set of adaptations to a parasitic life includes a development or acquisition of organs of attachment, such as claws to cling to skin, hairs, or feathers, or hooks and suckers to maintain position upon or within an unwilling host. Another effect of such a mode of life consists of modifications in reproduction. There are a few parasites living externally, which have restricted the output, and produce few young, which are carried by the mother for longer than the normal period, and are thus protected from many dangers. By far the greater number of parasites, however, adopt the opposite method, and endeavour to overcome the disability of their position by an enormously increased fertility. This increased fertility is often astounding, but is in proportion to the risks run and the losses involved in the often complex life-cycle.

Parasites may be classed according to their habits, as *ectoparasites* which confine themselves to the exterior of the body of the host, and *endoparasites* which live within the host, either in tissues or in the various cavities, and which feed either upon the tissues, or, as is the case with many intestinal parasites, upon the food within the gut. The former are as a rule the least altered by their mode of life, while the latter are generally greatly modified. Parasites can also be classed as *temporary* and *permanent* parasites. Among the first class are those forms which only visit the host to feed, while among the second are all possible variations from ectoparasites, which pass their whole life upon a host (or hosts), to the most specialised internal forms. Besides these two groups, we can recognise *periodic* parasites, which are regularly parasitic at certain stages of their life-cycle but free-living at

others. The highly modified forms have already been mentioned. They are often spoken of as showing marked degeneration; while this view is partially true, it is equally correct to regard them as highly specialised, and as showing a very high degree of adaptation to their surroundings (*environment*). Not only is this specialisation illustrated by the loss of some organs and the unusual development of others, but by a complexity of life stages, which in many cases is nothing less than startling. Such cases are without doubt the result of long series of evolutionary processes, and have resulted, in the more extreme cases, in linking together quite diverse types of animals in the life-cycle of a single parasite. In such a case the adult parasite inhabits a vertebrate host (mammal, bird, reptile, amphibian, or fish), whilst another and equally important part of the cycle is passed in an invertebrate host (arthropod, mollusc, etc.). In other cases both stages are in different vertebrate hosts, and so on. In one of these hosts sexual reproduction takes place, and this host is termed the *definitive host*, while the second host, in which asexual reproduction occurs, is termed the *intermediate host*. The actual passage from one host to the other may take place in various ways. In what is perhaps the simplest form, the ova produced by the sexual stage pass out into the external medium, and are there ingested by the intermediate host, while the final stage of asexual reproduction similarly passes out and is ingested by the definitive host.

The effects of parasites upon their hosts are as varied as the effect of parasitic life upon the parasite. In some cases, animals may harbour great numbers of certain parasites without being in any way affected, as far as we can judge; while in other cases a very few parasites will be sufficient to produce most grave results. As a general rule, however, the effect will depend upon one, or more, of the following factors:—the size of the parasite

relative to that of the host; the numbers present; the tissues or organs parasitised; the age of the host (young animals are generally more harmed than older ones); the amount of nutriment required by the parasite. In addition, some parasites produce *toxins* (poisonous substances) as a result of their life processes which have an injurious effect on the host apart from the direct damage done by the parasite.

Another and very serious aspect of parasitism (more particularly associated with temporary ectoparasites) is the transmission of disease—more particularly of blood or skin diseases. Examples of this will be given later.

The relations of parasites to wild animals are very interesting, since it is here that we can observe the phenomena of parasitism under natural conditions. It has already been pointed out that it is under these circumstances of natural environment and evolution that parasites have arisen. Under these conditions they are natural members of animal communities which are the outcome and result of long evolutionary processes; as members of these it is seldom that they assume the alarming and destructive phases seen under the unnatural conditions incident to domestication. The reasons for this are, that within these natural communities there exists a relative balance, brought about by the interaction of the various members making up the community, in their relations to one another, to the plant communities, and with the physical factors of their environment. Obviously, it is not to the benefit of the average parasite that the host should die prematurely, or become extinct, as, in such case, the parasite will die out also. This Struggle for Existence affects all animals and through them their parasites; although it must be noted that the more highly specialised internal parasites occupy a very special environment (while within the host) and are, to

a large extent, removed from participation in the general struggle for existence.

Man, by his interference with, and manipulation of, his environment, has to a very large extent disturbed or upset the natural balance or equilibrium, and has substituted plant and animal aggregates more useful to himself, and consequently of a very unstable character. The animals which he domesticated presumably already had their parasites, and it is probable that these, benefiting by the relaxation of competition in many directions owing to altered and unbalanced conditions, increased unduly amongst their domesticated (and possibly less resistant) hosts. Outbreaks of disease in animals (*epizootics*) due to parasites have their serious effects on man and his communities, since they bring about loss, not only to the individual, but through his lessened well-being to others about him.

Man, in the breeding and management of his domesticated animals, frequently commits such errors as unbalanced and unnatural feeding; keeping the animals in climates and upon lands unsuited to them, and for too long a period; overstocking; unsuitable housing; and so forth, very often with a resultant lowering of the general health and resistance of the animals concerned, and ensuring the undue multiplication of their parasites, practically without a check. The average farmer or breeder is only now beginning to realise that cases of loss are frequently due to preventable parasitic invasion, and to seek advice and assistance from those who are ready to place the necessary information and advice at his disposal.

In dealing with any parasite, it is of the utmost importance that a study should be made of its entire life-history in order to ascertain at what point attack can be most readily, economically, and satisfactorily directed; the search for the weakest link in the biologic chain.

The farmer or student may obtain information from, (*a*) the Agricultural Departments of Universities and Colleges. At most of these there are workers who can give aid within their area. England and Wales is divided into fourteen such areas or provinces, each of which is served by an Advisory Centre situated at a University or College, and at which are located specialist Entomologists, or Advisers in Veterinary Science, whose services are free to applicants (4), and who can in turn refer problems to (*b*) the Agricultural Research Institutes, where research is in the hands of staffs of specialists. In addition to this service set up by the Ministry of Agriculture, there are investigators on parasitological problems in many official or independent laboratories.

Agriculturalists are advised to lose no time in dealing with actual or suspected cases of infestation, but to call in competent aid forthwith.

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CHAPTER II

PARASITIC PROTOZOA

ONE of the fundamental ideas of modern Biology is that all living organisms—animals and plants alike—are composed of one cell or of an aggregation of many cells more or less modified according to their functions, and that these cells are all derived from pre-existing cells. A cell may be defined as *a mass of protoplasm, part of which is specialised to form a nucleus*. The word *cell* is perhaps an unfortunate one, since it conveys the idea of a cavity rather than of a mass ; it was applied by the early microscopists to the spaces seen in thin sections of dried plant tissues, and only later transferred to the actual living contents of these spaces.

The nature of a cell may best be explained by considering one of a simple type, such as the unfertilised ovum or egg-cell. In many cases this consists of a minute sphere of protoplasm—a semi-fluid albuminoid substance of very complex chemical structure (and probably a mixture of many compounds) which Huxley aptly termed the physical basis of life—in which can be seen a yet more minute sphere, termed the nucleus. There is good reason for believing that the protoplasm of the nucleus (often termed the *karyoplasm*) is chemically different from the *cytoplasm*, as the protoplasm outside of the nucleus is termed. Under a high magnification, and especially after suitable staining, it is seen that the nucleus itself has a somewhat complex structure in most cases. It is generally agreed that the nucleus is essential

to the life of the cell ; in many cases it has been demonstrated that a cell deprived of its nucleus dies after a variable period of time.

As has been stated above, all cells are believed to be derived from pre-existing cells. (The researches of Pasteur and others during the last century demonstrated that it was impossible to produce living organisms from non-living matter ; in the cases where this appeared to take place, it was shown that the conditions of the experiments had not provided for killing any organisms that were in the material previously.) The process by which new cells are formed is known as *cell-division*. In the typical cases the parent cell divides into two *daughter-cells*, which in their turn (when fully grown) produce a second generation of daughter-cells ; this is known as *binary division*. Among certain protozoa, as will be seen later, a modification of this is met with. In all cases of cell-division, as far as is known, division of the nucleus precedes division of the cytoplasm, which does not commence until the daughter nuclei are separate, as a rule. Nuclear division may be *amitotic*, when the nucleus divides directly into two halves (much as one might divide a piece of dough by constricting it in the middle until the halves break apart), or it may be *mitotic*, when a somewhat complex series of changes are passed through. An account of the changes in mitotic, or *karyokinetic* division (as it is also termed) is given in all save the most elementary text-books on either Botany or Zoology.

The mass of protoplasm constituting a cell may be covered with a cell-membrane secreted by itself or it may not ; it may also be of very varied shape. In many cells there are lash-like outgrowths of the cytoplasm, known as *flagella* when large and few in number, and as *cilia* when smaller and more numerous. Within the cytoplasm there are often visible various structures which do not concern us here.

The Phylum PROTOZOA (as defined by Wenyon (1)) is that subdivision of the animal kingdom in which all the unicellular animals are grouped. In addition, it contains certain colonial forms, which are essentially aggregations of undifferentiated cells which have remained more or less united after the divisions of the parent cells instead of breaking away and leading independent existences. By the latest writers the phylum is divided into two sub-phyla, the PLASMODROMA and the CILIOPHORA. The former group contains the more important parasitic species. By some of the older writers the CILIOPHORA, with the class MASTIGOPHORA (" Flagellata ") of the PLASMODROMA, are described under the title of *Infusoria*. Since none of the organisms dealt with here belong to the CILIOPHORA, we need make but few further remarks on that group.

Locomotion among the Protozoa is brought about either by cilia or flagella, which give rise to a swimming movement, or by a creeping or rather *flowing* motion, brought about by means of *pseudopodia*. To quote Wenyon (p. 31) these " are simply processes of cytoplasm which are formed from the surface of the body. A small elevation . . . occurs at any point and . . . gradually increases in size. . . . When it has reached a certain size it may be withdrawn gradually, and another formed in some other direction. On the other hand, it may increase steadily in size until the whole body of the organism flows into it. . . . It is by means of pseudopodia passed around any object that food-particles are ingested." Pseudopodia are characteristic of the class RHIZOPODA, but are also found in some flagellates (MASTIGOPHORA) and in SPOROZOA, such as the malarial parasite. Movement by means of them is often termed *amoeboid movement*, since it is typically shown by the amoeba, a protozoon described in most zoological works ; it may be remarked that amoeboid movement is exhibited by various cells in

nearly all animals, as, for instance, the white corpuscles of the human blood.

Nutrition is effected in two ways, if we put aside those Protozoa which have the power of existing on inorganic substances as do plants. The animal may ingest solid particles of proteid, either by surrounding it with pseudopodia, *e.g. Amoeba*, or through a definite mouth-pore in the cell-membrane. Alternately, the animal may obtain its proteid in solution, the nutrient fluid transfusing into the body; this is the case with many parasitic forms. When solid particles are ingested, they are seen to lie within small spaces known as food-vacuoles; the innutritious residue is expelled from the body, or, as in the case of *Amoeba*, left behind as the animal moves about. When the nutriment is obtained in solution, there are, of course, no food-vacuoles. Some of the food may be stored within the body for future use.

Reproduction may take place in two ways. One is by binary division, which has already been mentioned, or by a modification of it known as *shizogony*. This mode, which is found among the SPOROZOA, takes the form of repeated divisions of the nucleus before any division of the cell occurs; when the cytoplasm divides it does so into as many portions as there are daughter-nuclei. While these forms of reproduction are regarded as *asexual*, there is in many cases a mode of reproduction which may be regarded as *sexual;* this is known as *syngamy*. There are two forms, each characteristic of one of the two sub-phyla. Among the PLASMODROMA, two individuals (*gametes*) which may differ in size and in structure fuse together permanently; the products of fusion may undergo a considerable developmental series before the normal asexual type of animal reappears. The gametes are often specialised cells, formed by binary division, but developing in a different manner to the usual cells. Among the CILIOPHORA, two similar

(and unspecialised) individuals unite together temporarily; during the union an interchange of nuclear substance takes place. After separation, the asexual type of division is at once resumed. It may be remarked here, that there is evidence to show that some, at least, of the CILIOPHORA cannot continue asexual reproduction beyond a relatively limited number of generations without losing first the power of entering into syngamy and then of undergoing binary division, and finally dying; on the other hand, in the case of certain SPOROZOA, of which we may cite the parasite of benign tertian malaria, recently studied by Yorke and Rees Wright (2), the organism can reproduce sexually after a very long series of asexual reproduction.

The PLASMODROMA are PROTOZOA, in which movement is effected by pseudopodia or flagella, and syngamy, where it is known, takes place by the complete fusion of gametes.

Of the four classes into which the group is divided, three contain important parasites of man or of live stock. Among the first class, the RHIZOPODA, which are predominantly amoeboid, there are no important parasites of farm stock, but species of *Entamoeba* and allied genera are found in man, one of which (*E. histolytica*) is the cause of a grave form of dysentery.

The two other classes include a number of forms which are important parasites of man and of animals, more especially in tropical and subtropical countries. Among the MASTIGOPHORA there are no really important parasites in Great Britain; the SPOROZOA include several forms of importance to the farmer.

The MASTIGOPHORA may be defined as PLASMODROMA, among which the predominant stage is flagellate, and for this reason the class is sometimes referred to as the *Flagellata*. The main parasitic forms belong to the sub-class ZOOMASTIGINA. It is believed that one of the

causes of "blackhead" in turkeys, a rather peculiar organism known as *Histomonas meleagris* ("*Amoeba meleagris*" of many writers), belongs to the family MONADIDAE, a division of the sub-class. The organism appears to be a flagellate with from one to three flagellae, living free in the intestine but occasionally invading the tissues of the intestinal wall and the liver.

Far more important than *Histomonas* are the members of the family TRYPANOSOMIDAE. Many of these organisms are the causative agents of grave diseases in man and in live stock, more particularly in tropical Africa, but also almost throughout the tropical and subtropical belt. The genus *Leishmania* contains several species causing disease in man, including the grave malady Kala-azar in Asia. The genus *Trypanosoma* contains several very important species abroad, and, although the species found in this country are of no great importance, demands some mention.

Typically, a trypanosome is narrow, elongated, and flattened, with a sinuous outline. The nucleus is conspicuous, and is situate near the middle of the body. Posteriorly, the flagella is seen to originate from (or near) a small granule (the *blepharoplast*) in the cytoplasm; emerging from the body, it runs forwards close to the margin, to which it is bound by an extension known as the undulating membrane. The flagellum may continue free for some distance beyond the body, or it may terminate at the anterior extremity, with at most a very short free portion. In the typical life-history, forms such as have been described are found in the blood of the vertebrate host, while in the invertebrate host, which may be an Arthropod or a leech, other forms occur.

In the vertebrate host, multiplication is by binary fission. In the invertebrate host, multiplication is also by binary fission; the parasites develop into forms which closely resemble the flagellates (*Crithidia*, *Herpetomonas*)

normally found in insects. It is not definitely known if syngamy occurs.

Among the more important trypanosomes may be mentioned *T. gambiense* and *T. rhodesiense*, the causes of African sleeping sickness; these are conveyed by flies of the genus *Glossina*. *T. brucei* (probably identical with *T. rhodesiense*) is the cause of serious disease among live stock, and is also transmitted by *Glossina* spp. In the case of these three trypanosomes various species of antelope act as reservoirs of infection. In Asia *T. evansi* is the cause of a disease among horse and other animals known as *surra*. It is said to be conveyed by species of *Tabanus*. *T. equiperdum* is the cause of a disease of horses known as dourine, in this case transmission is direct. This disease is of great importance in many countries outside the tropics.

The trypanosomes of mammals are represented in this country by *T. lewisi* of the rat (transmitted by the rat-flea, *Ceratophyllus fasciatus*) and *T. melophagi* of the sheep, transmitted by the sheep ked, *Melophagus ovinus*. *T. melophagi* has been studied by Hoare: it appears to be fairly common among sheep, but is, as far as is known, quite harmless.

SPOROZOA.—This class includes PROTOZOA, which are exclusively parasitic in habit, and which inhabit the cells and body fluids of vertebrate and invertebrate animals. There are two sub-classes each containing two orders, of which only one order, the COCCIDIIDA, concerns us here. In this, the parasites are nearly always *intracellular* (*i.e.* within cells) during the period of growth. Asexual reproduction by shizogony; finally sexual forms (*gametocytes*) are produced, the males and females developing independently of each other. The order is divided into three sub-orders, each of which contains very important parasites of man or of live stock. Of these sub-orders the EIMERIIDEA and PIROPLASMIDEA are of importance here.

Among the EIMERIIDEA, various species of the genus *Eimeria* (formerly known as *Coccidium*) are responsible for a group of diseases among animals and birds known as *Coccidiosis*.

Eimeria stiedai * (generally and incorrectly called *Coccidium oviforme*) is responsible for a common and often destructive liver disease among both wild and tame rabbits. The shizogonous cycle takes place within the cells lining the bile-ducts of the liver; the daughter cells (*merozoites*) formed by division escape through the rupture of the infested cell, and enter the ducts; from here they enter fresh cells, where the process of shizogony is repeated. Finally certain merozoites develop into *micro-* (male) and *macro-* (female) *gametocytes*. The microgametocyte produces a number of microgametes, each provided with two flagella, while the macrogametocyte gives rise to a single macrogamete which forms round itself an *oöcyst*, with a minute pore for the entrance of the microgamete. The microgametes escape into the bile-ducts, where they swim about in search of a macrogamete. After fertilisation the oöcyst wall thickens. If the oöcyst escapes from the rabbit's body (by passing down the bile-duct into the gut, and out with the faeces) it undergoes a series of changes which ultimately result in the formation of four *sporocysts*, each containing two *sporozoites*, within it. If oöcysts at this stage are ingested by a rabbit, the sporozoites are liberated in the intestine, and invade the liver. Besides passing out with the faeces, oöcysts may be liberated by the death of the host and the subsequent disintegration of the tissues.

When an infected liver is examined, white or yellow

* According to the Zoological Code (Article 14), a specific name which is a noun in the genitive is to be "formed by adding to the exact and complete name, an *i* if the person is a man . . .," hence this species must be E. steida-*i*, and not steida-*e*, as the rules of Latin grammar demand. [Wenyon, p. 1339, and Brumpt, p. 132 (footnote).]

nodules will be seen, which are the enlarged and altered bile-ducts and surrounding tissue ; this appearance has given the disease its popular name of " spotty liver."

Eimeria zürnii is an intestinal parasite of cattle, in which it often causes epizootoics. Apart from the site of infection, the life-cycle is similar to that of *E. stiedai*. The disease generally takes the form of an acute enteritis or dysentery.

Eimeria avium is an intestinal parasite of birds, and has been recorded from ducks, geese, chickens, and turkeys, as well as from grouse and other game birds. It has been held responsible for " blackhead " in turkeys, and for an epizootic among young grouse in Scotland, while it apparently gives rise to grave epizootics among newly-hatched chickens. It is frequently found in healthy birds, but heavy infestation occur only in sick birds ; it is difficult to say whether " the symptoms are entirely due to the coccidia or whether some other disease has lowered the resistance of the bird and enabled the coccidial infection to extend beyond the usual limits " (Wenyon, p. 857).

In the case of an outbreak of coccidiosis among domestic rabbits, fowls, etc., the healthy animals or birds should at once be transferred to new quarters, preferably at some distance from the infected ones. Faeces from the infected stock should be destroyed (preferably by burning) and the premises thoroughly cleaned, disinfected, and lime-washed.

The PIROPLASMIDEA are divided into two families, the BABESIIDAE and the THEILERIIDAE. They all are parasites of the red blood-corpuscles of mammals, and many of them cause grave diseases of stock. Much remains to be done in connection with the study of these parasites ; fortunately the mode of transmission is well established in most cases, though little or nothing is known of the developmental stages. One of the BABE-

SIIDAE, *Babesia bovis* (*Piroplasma divergens*) is of considerable importance in Britain, as it causes the disease of cattle known as " redwater."

The protozoa included in the genus *Babesia* are parasitic in red blood-corpuscles, in which they do not produce any pigment (this serves to differentiate them from the parasites of malaria, which produce a dark pigment from the haemoglobin of the blood). Division within the cells is into two or four daughter parasites,

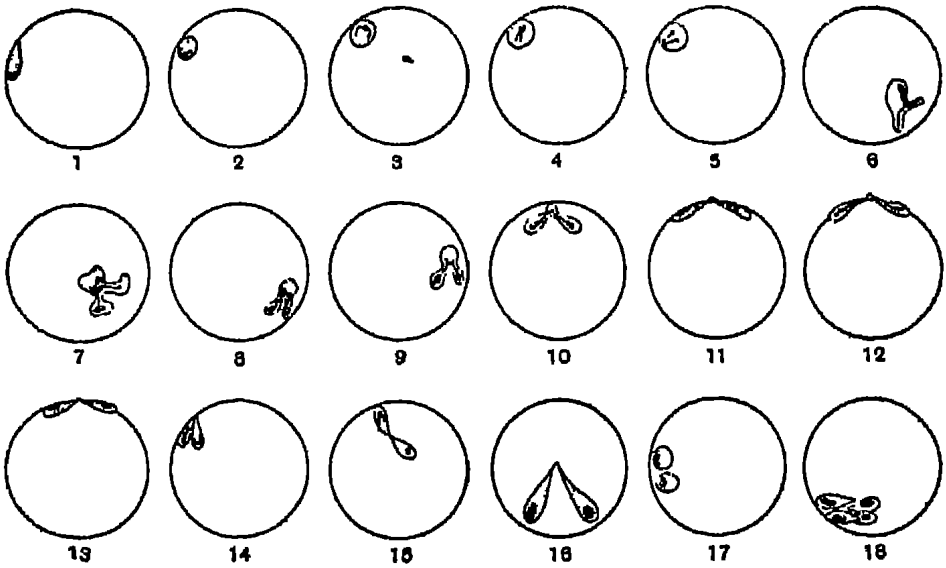

FIG. 1.—Life-history of *Babesia bovis* (*Piroplasma divergens*). [After Nuttall.]

somewhat pear-shaped after division, and often joined by the small ends. Single parasites are round, oval or irregular in shape. *Babesia bovis* is a small species, the largest forms not being more than 1·5 μ in diameter. It is conveyed by a tick, *Ixodes ricinus*, and it has been found that the parasite may be transmitted from one generation of ticks to another through the egg, as well as from one larval stage to the next.

There are a number of other important piroplasms of cattle, of which *B. bigemina*, an American and African

species transmitted by ticks of the genus *Margaropus* (*Boophilus*), and *Theileria parva* (family THEILERIIDAE), an African species causing a serious disease known as East Coast Fever and transmitted by ticks of the genus *Rhipicephalus*, may be mentioned. For further information the student is referred to Wenyon and the references there given.

Ticks are described in a subsequent chapter, where their connection with "red-water" disease and the method of control, etc., are discussed.

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CHAPTER III

PARASITIC PLATYHELMINTHES—TREMATODES (FLUKES)

THE parasitic flatworms belong to the Phylum PLATYHELMINTHES, which embraces a large number of parasites of animals and man, as well as some free-living forms.

In the majority the body is flattened and either leaf-shaped or tape-like in general form. The phylum is divided into three classes, the first, called the TURBELLARIA, containing worms which for the most part live free in water or on land, only a few being parasitic. Several small species are abundant in our ponds and ditches, whilst in the tropics quite large and brightly coloured land forms are found.

The second class, the TREMATODA or flukes, includes many important and injurious parasites, usually leaf-like in form, some being external parasites, others internal. The class is further characterised by the possession of one or more adhesive suckers, a gut which forks into two blind sacs (which are much branched in the genus *Fasciola*), and a complex excretory system. Most species are hermaphrodite (having both male [♂] and female [♀] reproductive organs) and self-fertile. The life-history is usually complex, and involves two or more hosts in most cases; in a great many it is still only imperfectly known. Trematodes infest various organs of the body, but chiefly the liver, intestines, and blood vessels. Whilst a large number of different species of flukes are found parasitic in both vetrebrate and invertebrate animals, comparatively few attack domestic animals

in Great Britain, the chief being the common Liver-Fluke, *Fasciola hepatica* (*Distomum hepaticum*), which is both widespread and abundant, and the cause of very serious losses to farmers in many districts.

As has already been stated, the body is flattened and leaf-like in outline ; it is from one to three cms. long on the average and about one cm. broad. It is generally pale in colour, often darker at the margins (this is due to the presence of food in the gut branches). Anteriorly there is a short triangular projection, at the apex of which is situated the *oral* or anterior sucker, which surrounds the mouth. The *ventral* sucker is somewhat larger than the oral ; and is situated on the ventral surface somewhat posterior to the base of the triangular projection. The *uterus* is a long convoluted tube posterior to the ventral sucker ; in mature worms it is seen to be full of eggs. The ovary is situated about the middle of the body, generally on the right side, and various accessory glands are grouped together near to it. The testes are diffused throughout the body. There is an excretory system consisting of special excretory cells (" flame-cells ") and their ducts. It is generally believed that *F. hepatica* is self-fertile.

F. hepatica occurs in the bile-ducts of the liver, and is an important parasite of sheep and cattle ; whilst horses, rabbits, and man are among other hosts.

Like most endoparasites, the liver-fluke possesses great fertility, and produces an enormous number of eggs which are passed out of the host animal in thousands. The *eggs* are oval in form, yellowish or brown in colour, with an *operculum* (a cap or lid) at one end, and measure about 140 μ in length by 80 μ in breadth. On reaching the exterior, and given suitable conditions of moisture and temperature, the eggs hatch ; under the most favourable conditions this takes rather over three weeks ; the larva escaping by pushing off the operculum. This

PLATE I

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FIG. 1.—*Fasciola hepatica*, × 6
FIG. 2.—*Limnaea truncatula*, × 12.

FIG. 3.—*Limnaea peregra*, × 6.
FIG. 4.—*Limnaea palustris*, × 6

larva (which is known as a *miracidium*) is provided with hair-like cell out-growths, or *cilia*, by the action of which it is enabled to swim ; it is elongated, tapering posteriorly, and is provided with " eye-spots." It is necessary that within a short period this larva should come in contact with a fresh-water snail of the genus *Limnaea* (in this country, *L. truncatula*) into the tissues of which it forces its way with the aid of a small anterior projection.

The snails of this genus are widely distributed, a number of species occurring in Britain, and are generally known as Pond-snails ; they live in shallow water and are vegetable feeders. *L. truncatula* occurs almost everywhere in the British Isles, and is found also in Europe, North Africa, parts of Asia, etc. (1), (2). The shell is conical and elongate, of a light-brown horn colour, with five or six whorls and a pointed spire. The mouth aperture is about half the height of the shell, and an altitude (height) of 12 mm. may be reached. This little snail favours clay or firm-bottomed ditches and streamlets, and is rare on peaty soils. It prefers shallow, well-aerated waters, and during wet periods soon colonises flooded and damp lands, persisting thereon as long as it can obtain a small amount of moisture, but soon succumbing to actual drought conditions. Its food consists of diatoms, etc. Breeding commences in spring and continues throughout the summer, ova being deposited in small gelatinous masses on mud, dead leaves, water-plants, etc. The eggs soon hatch and the young snails continue to grow throughout the year unless interrupted by drought or frost. The snails are self-fertile, and can commence to oviposit at an altitude of from 4 to 4·5 mm. (3), (4).

It should be mentioned that several other very common species of *Limnaea* occur, in similar situations, and may easily be confused with *truncatula*, especially in their younger stages. *L. pereger** has a larger shell of lighter

* Commonly, but incorrectly, known as " peregra."

colour, the largest whorl occupying nearly the whole of the shell, the spire being much less pronounced and the aperture wider, while it frequently grows to a considerable size. This species has been accused of acting as an intermediate host for the liver fluke, but this has yet to be proved conclusively. *L. palustris* more resembles *truncatula*, but is larger, darker, and by no means so abundant or so obiquitous in its distribution. *Aplexa hypnorum* may likewise be found in similar situations, as well as *Succinia putris*.

The miracidium enters the wall of the branchial chamber of the snail, and there undergoes changes resulting in the formation of a *sporocyst;* this is a thin-walled sac with a rudimentary excretory system, but no digestive organ. From the internal wall of the sac "germ-balls" are budded off which develop into the second stage, the *redia*. This is also a thin-walled elongate sac; it has a more elaborate excretory system, and also a digestive organ consisting of a muscular *pharynx* and a blind, thin-walled digestive sac. The rediae escape by rupture of the sporocyst, and migrate to the "liver" of the snail. Within the redia, *daughter rediae* are formed by budding from the internal surface of the wall, and escape from their parent through a *birth-pore* near the anterior end. The rediae move about through the liver tissue, and it is probable that two outgrowths in the posterior half of the body (the posterior processes or *procruscula*) play a part in the locomotion. The redia gives rise, by internal budding, to a third stage, the *cercaria*. In spring and early summer both daughter rediae and cercariae are produced, while in late summer and autumn cercariae only are found within the rediae. The cercaria of *F. hepatica* has an oval body, with two suckers and a tail. There is an excretory system, and a simple biforked gut, while rudiments of the genital organs are also present.

PLATE II (*a*)

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FIG 1.—*Fasciola hepatica*. Egg, containing miracidium, × 350.
FIG 2.—*F. hepatica*. Redia (from a specimen stained with carmine), × 35.
FIG 3.—*F. hepatica*. Cercaria (from a specimen stained with iron-haematoxylin), × 50.
FIG 4.—*F. hepatica*. Cercaria encysting (from life), × 70.

The cercariae escape from the parent redia by the birth-pore, and emerge from the snail into the surrounding water. Here they swim about actively for a short time, after which they settle on grass or water-plants (or when the snails are in specimen tubes, on the glass sides) cast off their tails, and excrete cysts around themselves. When the grass or other material bearing the cysts is eaten by a sheep or other host animal, the cyst wall is dissolved in the intestine, the larval flukes burrow through the gut wall into the body cavity, and from thence gain access to the liver, penetrating through the tissues to the bile-ducts, where they develop into adult flukes.

The development of *F. hepatica* was first investigated, and the larval stages described, by Thomas (5); the redia, cercaria, and cyst have recently been studied by the junior author (6).

In addition to *F. hepatica*, another species, *F. gigantica*, which is much larger, is stated to occur in Great Britain, as well as *Dicrocoelium lanceolatum*, often called the Little Liver-Fluke. In addition, a number of other species occur in various domestic and wild animals, but are not of great economic importance.

From time to time, losses from *F. hepatica* have assumed very serious proportions, chiefly among sheep, but also among cattle. These losses, whilst more or less usual on heavy, ill-drained, or swampy land, where they may occur even in relatively dry climates and normal years, are conditioned by weather, and follow a continuance of wet, sunless periods, particularly in summer, when the dry periods are not sufficiently prolonged to check the natural increase and spread of the host snail. Farmers who have to deal with infected land or stock are strongly advised to get reports as to the condition of the livers of sheep sent for slaughter, and to take every opportunity of making such examinations personally. Rabbits shot or found dead should also be

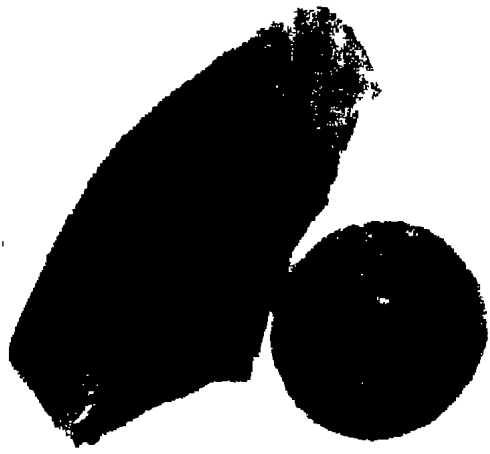
opened and the livers examined, but it is necessary to point out that the diseased condition known as "spotty liver" (*coccidiosis*) is of frequent occurrence and is often mistaken by farmers and others for fluke infestation.

The host snail (*L. truncatula*) should be sought for, and if present dealt with by means of copper sulphate (bluestone), which may be applied either as a spray, as a dust, or broadcast (7). In spraying, any efficient knapsack or horse-drawn machine can be employed, according to the nature of the area to be dealt with. Solutions of one per cent. are efficient, but allowance should be made for dilution owing to water present, and for general purposes from one to two per cent. are recommended. A solution of one per cent. can be made by dissolving 1 lb. of copper sulphate in 10 gallons of water. The amount of fluid required for spraying land has been found to average from 100 to 120 gallons per acre. A dust can be made by mixing 1 part by weight of finely ground copper sulphate with 4 parts of kaolin (china clay) or flour. This can be applied (more especially to narrow ditches and other small areas) by hand-dusting machines or other larger apparatus.

Broadcasting is more applicable to wider areas and farm practice, and consists of spreading a mixture of 1 part finely ground copper sulphate and from 4 to 8 parts of fine dry sand, at the rate of $1\frac{1}{4}$ to $2\frac{1}{4}$ cwts. per acre. This can be done by hand or machine, but must be as even as possible.

In all the above methods stock should be excluded from the treated land for several days, and care should be exercised that unduly large amounts of copper sulphate are not employed by unskilled workers. In all cases the cost is comparatively low. It should be mentioned here, that it is possible to have the host snails present without infestation, but they are a serious potential danger, and should be treated as such.

PLATE II (*b*)



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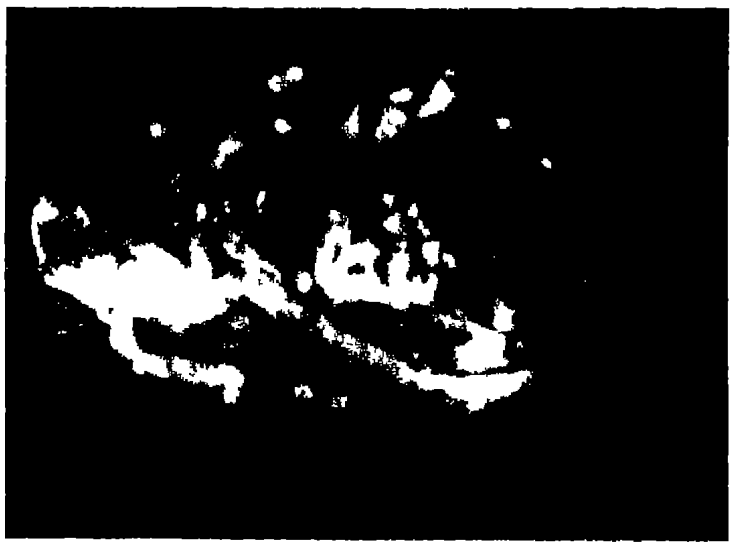

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FIG 5.—*F hepatica*. Ruptured cyst, × 75. (From life. The encysted cercaria is the rounded body on the right, while on the left can be seen the ruptured cyst envelope.) (Figs. 3, 4, and 5 are reproduced from "Studies on Larval Trematodes from North Wales," by kind permission of the Editors of *Annals of Tropical Medicine*.)

FIG 6.—Dissection of a specimen of *Limnaea truncatula* infested with rediae and cercariae of *F. hepatica* × 6.

Dosage has recently received considerable attention, and can now be regarded as cheap, safe, and effective; all sheep exposed to infection should be treated forthwith (8), (9). The two chief substances used are male fern and, more recently, carbon tetrachloride. Advice as to treatment is best obtained from the veterinary authority. It may further be mentioned that dosage may be used as a safeguard as well as in cases where symptoms of infection have actually appeared.

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CHAPTER IV

PARASITIC PLATYHELMINTHES—CESTODES (TAPEWORMS)

THE third class of the PLATYHELMINTHES is the CESTODA, or Tapeworms. These are all parasitic. A typical member of the group consists of a head, or *scolex*, which is generally globular in shape, and in the species parasitic in farm stock is furnished with four roughly circular lateral *suckers*. In addition to the suckers, many species are provided with a large number of thorn-shaped hooks borne on a frontal projection known as the *rostellum*. From below the scolex are budded off (generally) a great number of segments, or *proglottides*, which together form the *strobila*. A short portion of the strobila immediately behind the scolex is usually not differentiated into distinct segments, and is often termed the "neck." The proglottides are flattened dorso-ventrally. Each proglottis contains male and female reproductive organs, which may have a common opening on one lateral edge of the segment (*e.g. Taenia*) or there may be openings on both edges (*e.g. Dipylidium*), in which case there are two sets of genital organs, or there may be openings on the ventral surface. In some species (but not in any of those dealt with here) there is a separate pore for the extrusion of the eggs. There is a simple excretory

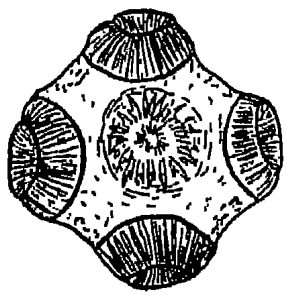

FIG. 2. — *Taenia solium*. Scolex, anterior view. [From Brumpt after Blanchard.]

system, consisting of a lateral vessel on each side, running the whole length of the strobila, with a transverse vessel in each segment. There is no gut; the worm obtains nutriment by transfusion from the semi-fluid contents of the intestine, to the inner wall of which it is attached by the suckers and hooks (when present) of the scolex.

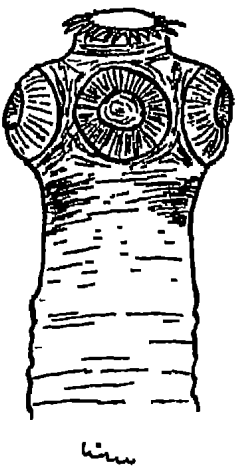

FIG. 3. — *Taenia solium*. Scolex. [After Leuckhardt.]

The whole worm may perhaps be regarded as a colony of sexual individuals budded off by an (asexual) individual specialised for the purpose of attachment. In the proglottides near the scolex relatively little can be seen of the internal organs. As the segments move away from the scolex (through the appearance of fresh segments nearer the head) the sexual organs develop, till at about half the length of the worm they are mature. At this stage fertilisation occurs; the segments are believed to be self-fertile, but it is probable that the adjacent segments fertilise each other. The male reproductive organs consist of *testes* which are diffused through the greater part of the segment, a *vas deferens*, and a protrusible and very long *cirrus*, or male intromittent organ. The female organs include a pair of *ovaries*, with various accessory glands, a *vagina* by which the spermatozoa enter at copulation, and a *uterus* within which the eggs develop. As a rule the male and female ducts open into a common *genital atrium* or pore. In the posterior segments the male organs degenerate, as do the greater part of the female organs, until the segment becomes nothing more than a sac full of eggs. The ripe segments break away, and may either be passed out with the faeces in an entire condition, or may disintegrate in the gut, when only the eggs are passed out.

The egg is roughly spherical; it consists of a wall of two or three layers surrounding a sac in which the embryo is found. Typically the embryo is a spherical body provided with six hooks, hence termed a *hexacanth* embryo.

The development is indirect, and in nearly all of those few cases in which it has been worked out, involves an intermediate host. When the egg is ingested by a suitable host, the outer coats are dissolved, and the hexacanth embryo bores its way through the inner coat.

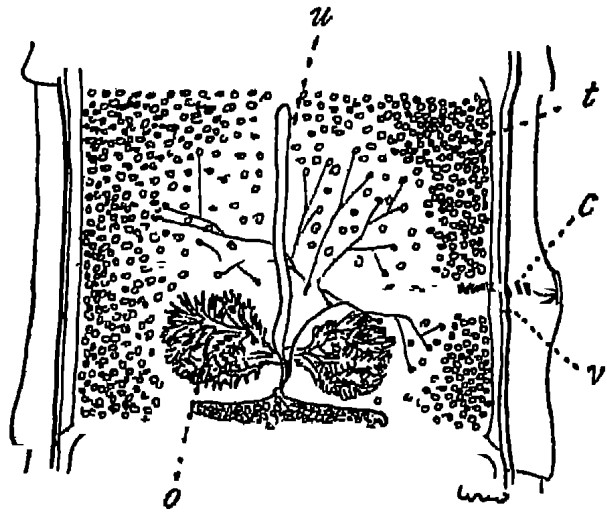

FIG. 4.—Segment of *Taenia saginata*. [From Brumpt after Sommer.] *u*, uterus; *o*, ovary; *v*, vagina; *t*, testes; *c*, cirrus.

Free in the gut, it enters the gut wall, and in the case of a vertebrate host probably enters the blood or lymph vessels, by which it is carried to any part of the body. Arrived at its destination, it develops into a larva of one of four types; two of these give rise to a single scolex, two to a number of scolices. Where a single scolex is formed, the larva may be a *Cysticercus*, or "bladder-worm," which has a large fluid-containing sac, or a *Cysticercoid*, in which the sac is vestigial. In the case of a larva giving rise to many scolices, these may be formed

directly on the inner wall of the fluid-containing sac into which the larva develops (*Coenurus*) or within daughter sacs budded off within the primary (*Echinococcus*). The presence of the cysts may give rise to grave disease in the animal infested, as in the "gid" or "sturdy" of sheep, or the hydatid disease of cattle and man. When the intermediate host is an invertebrate (as in the case of *Dipylidium caninum* of the dog, conveyed by the dog-flea) the development is in the body-cavity (*haemocoele*) or the tissues.

The definitive host is infected by eating tissues containing cysts. In the intestine the scolices are liberated, and become attached to the mucous layer of the wall.

It has been mentioned above, that in at least one case development takes place throughout in one host. This is so in *Hymenolepis nana*, a small tapeworm found in man and in the mouse. The embryos are liberated in the upper part of the small intestine, where they burrow into the wall and develop into cysticercoid larvae. The larvae, when mature, fall out into the gut, and develop into adult worms in the lower part of the small intestine.

Tapeworms of the genus *Anoplocephala* infest the horse, and may be found in the colon, small intestine, and caecum. The scolex is large and unarmed. The segments are very short, but wide, the broadest being situated posteriorly. The life-history is unknown.

Several species are found in Britain, none of which, however, occur in great numbers, as a rule, and they do not seem to be especially harmful, except when in large numbers. It may be noted, however, that more than 1,000 individuals of *A. perfoliata* have recently been recorded from a single horse (6).

The genus *Moniezia* contains the so-called "broad tapeworms" of ruminants. The segments are generally broader than long, and longer than thick. The genital organs and their pores are double in each segment. The

scolex is unarmed. There are differences of opinion as to the number of species occurring in this country, but three are generally recognised, *M. expansa*, *M. planissima*, and *M. alba*. These forms, however, cannot be identified without careful preparation and examination. The greater number of the tapeworms that are frequently so abundant in slaughter houses, etc., more especially in May, June, and July, belong to the first two species mentioned above. These worms inhabit the small intestine and occur practically wherever sheep are at all plentiful, whilst in certain districts they are extraordinarily abundant. They are most prevalent on the low-lying and damper pastures, and there are few records from the hills and upland sheep-walks. Although found in cattle and sheep of all ages, lambs are the most seriously affected, and more than one species may occur in the same host. These worms may attain a length of several yards; they are white to yellowish in colour. There is little doubt but that heavy infestation causes serious symptoms in lambs, retarding growth, and producing emaciation, anaemia, etc. It would seem, however, that considerable numbers may be present without undue disturbance, since fat lambs, when killed, are frequently found to harbour them. In a recent case in North Wales, a fat lamb yielded 43 individual worms totalling 125 feet in length (5). In many cases fattening is retarded, whilst in some instances death may occur. Infestation may be detected by examining the faeces for ripe segments which frequently appear when lambs are not more than seven or eight weeks old, and treatment should then be resorted to as a precautionary measure. The fact that light to moderate infestations may be of regular occurrence leads some flock-masters and shepherds to believe that these worms are negligible; but in heavily infested areas the opinion is otherwise (2). Despite the very considerable amount of research work conducted, the

life-histories of these parasites remain entirely unknown, and it is therefore impossible to take preventive measures, other than the removal of lambing flocks from land known to be infective.

In treatment many of the well-known anthelminthic drugs have been employed. Liquid extract of male fern may be used and a combined solution of sodium arsenite and copper sulphate has been recommended. One of these should be adopted under veterinary advice.

Dogs harbour numerous tapeworms, several of which are important pests. *Dipylidium caninum* is one of the commonest, and the segments are peculiar in form," being longer than wide and shaped somewhat like a cucumber seed " (7). The life-history of this species has already been mentioned.

Taenia hydatigena (*T. marginata*) is another species found in dogs. Its larva is a large cysticercus not infrequently found in the peritoneum of sheep and cattle and known as *Cysticercus tenuicollis*.

T. pisiformis (*T. serrata* of some writers) of the dog occurs commonly as *C. pisiformis* in the mesentery of rabbits.

Multiceps multiceps (*T. coenurus*) gives rise in the larval stage to the very serious condition known as " gid " in sheep (also known as " turnsick," " sturdy," " bendro," etc.). This condition chiefly affects young sheep, more especially in the rougher or more mountainous type of country and where there is abundant moisture. Ripe segments on passing out from the dog disintegrate in due course, and the ova are ingested by sheep during grazing or drinking. The embryo worms are released in the intestine and penetrate into the blood-stream by which they are carried to the tissues; only those reaching the brain or spinal cord are able to complete their development. After some wanderings in these regions the larvae settle down, lose their hooklets, and transform into small

cysts which rapidly increase in size and finally attain a diameter of from 3 to 5 cms. One cyst is usually found, although more may be present, generally situated on the cerebral hemispheres. Pressure from the growing cysts upon the brain brings about the curious symptoms designated " gid," which vary somewhat according to the location of the cyst. Affected sheep become dull and may walk in a circular manner, or the head is held high or low, etc. The powers of guiding locomotion and of sight are seriously impaired, the sheep ceases to feed, and if not treated will die, generally in the ninth month after attack (3). Young cattle may also be similarly affected. The only successful treatment is surgical. In many cases the mature cyst will bring about a softening of that part of the skull immediately above it, and can thus be located by touch. When this condition is attained, operation can usually remove the cyst, with the subsequent recovery of the sheep. This operation requires to be carefully performed, and sheep may be lost through clumsy or careless handling; skilled aid should therefore be sought.

Prevention, on the other hand, is feasible, and should be the aim of all sheep-breeders. The most important item is the prevention of infection in dogs, by rendering it impossible for them to ingest the ripe cysts. To this end the head (or brains) of any sheep which has died of this disease should be carefully and thoroughly destroyed. Perfunctory burial is not sufficient; the head should be cooked, or, for preference, burned. Otherwise, roving dogs may obtain the head and extract and devour the brain and cyst. This merely emphasises the danger, to the sheep-owner, of the uncontrolled dog. The other necessity is the regular dosage of all farm dogs, thereby preventing the infection of the pasture. It is recommended that this be done every two months, the dogs being confined after treatment and all expelled worms

collected and destroyed. The application of these simple measures will speedily reduce the number of cases, and concerted action will rapidly eliminate this disease altogether. As it is, this parasite is becoming less abundant in many districts.

Echinococcus granulosus (*Taenia echinococcus*) (1) is another dog tapeworm which in its larval stages may cause serious disease in sheep, cattle, pigs, and also in man. The worm is small and always less than 5 mm. in length, but in the cyst stage an enormous number of larval heads are developed. The cyst, which will develop in any organ of the body, more especially in the liver, is usually firm-walled and roughly spherical in form, and may attain to large dimensions. Within the tough external cyst wall lies the germinal membrane, whilst the cavity is occupied by a fluid. From the germinal membrane arise further cysts, each developing a number of larval tapeworm heads, and these cysts either separate and pass free into the fluid or bulge outward from the wall of the mother cyst, giving rise to an irregular cystoid mass. Under careless and insanitary conditions this parasite may become abundant and cause serious infestation in man, which may end in death. The destruction of all infested organs and the periodic treatment of dogs (as in " gid ") are the measures to be adopted. Infested organs or carcases may be buried deeply in quicklime.

Taenia solium, commonly known as the pork or armed tapeworm, is another dangerous species, which occurs in pigs and other animals, and man. The worm may attain a length of from 6 to 9 feet, and comprise 800 to 900 segments. The larvae (*Cysticercus cellulosae*) develop in many animals, and chiefly invade the muscles of the host, where great numbers may become encysted. Infestation in man generally arises through the ingestion of raw or insufficiently cooked infested flesh (pork). This disease is rare in Britain,

Taenia saginata is an unarmed species occurring in man, the larva being a cysticercus in the muscles and connective tissue of the ox.

Wild rabbits are frequently infested by tapeworms, of which *Cittotaenia denticulata* appears to be the most abundant. In addition, two larval cestodes are found in them, *Cysticercus pisiformis* (already referred to) on the mesentery, and *Coenurus serialis* in the subcutaneous tissues (4). The adult form of this last occurs in the dog.

Poultry are infested with a number of cestode worms, some of which may cause severe loss. Most of them belong to the genus *Davainea*. The life-histories are comparatively little known, although in one instance the larval stages occur in common slugs. Earthworms, insects, and other invertebrates are suspected or likely hosts. The tapeworms are generally of small size and may quite readily be overlooked and unsuspected as a cause of trouble in the flock. Affected birds may become very thin, pale in the comb, and show the usual symptoms exhibited by all sick birds.

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CHAPTER V

PARASITIC NEMATHELMINTHES—NEMATODA (ROUNDWORMS)

THE parasitic Roundworms are included in the Phylum NEMATHELMINTHES, class NEMATODA. The Phylum has been defined (9) as "unsegmented animals, without appendages arranged on a definite segmental plan; with a body-cavity in which the organs float; usually elongated, cylindrical or filiform (hairlike); with a body-cavity in which the organs float; sexes usually separate." There are two classes, NEMATODA, with a gut, but no proboscis, and ACANTHOCEPHALA, without a gut but with a proboscis, usually protrusible, and almost invariably furnished with hooks. The ACANTHOCEPHALA are all parasitic, and are sometimes known as "thornworms." Southwell and Macfie (8) have published a short study of the group to which the student is referred. The NEMATODA are divided into two classes, EUNEMATODA and GORDIACEA, the latter, often known as "hairworms," do not concern us here; in them the alimentary canal degenerates and disappears in the adult worm.

The NEMATODES are circular in cross-section. Externally there is a resistant cuticle. Immediately beneath this is the hypodermis, while the innermost layer of the body-wall is muscular. The body-cavity is continuous throughout the body, and the digestive and reproductive organs lie free within it. The alimentary canal runs from one end of the body to the other. The anterior portion of the gut consists of the *vestibule*—a simple tube which leads from the external opening,

but which is not always present—and the oesophagus. This may be a simple tube, or may be provided with diverticulae; it may be very varied in shape, being either a straight tube, or expanded into a spherical bulb at the posterior end, or constricted in various portions, etc. The *mouth* may be a simple opening at the anterior end, with or without *lips* surrounding it, or it may be situated at the base of a more or less globular depression or cavity (lined with cuticle) known as the *buccal capsule*. The buccal capsule may be provided with teeth on various parts of its surface, or with cutting plates more or less surrounding its opening to the exterior, or with both plates and teeth.

In the male the genital system consists of a long blind tube opening, together with the alimentary canal, into a posteriorly situated common passage or *cloaca*. The posterior portion of the body may be modified into a *genital* or *copulatory bursa* surrounding the opening of the cloaca; this is characteristic of the STRONGYLOIDEA among the worms dealt with in this book. There are generally one or two retractile *spicules* situated in the tissues alongside the cloaca, into which they are protruded, passing through the external opening, during copulation. In the female the genital system consists of one or two tubes opening at the *vulva*, which is situated in the mid-line of the ventral surface of the body (though in some worms the opening appears to be lateral, owing to a tortion or twisting of the body).

The EUNEMATODA includes forms parasitic on animals and plants, as well as free-living forms. Among the parasites of animals we find various types of life-cycle. *A*. Forms with alternation of sexual and asexual reproduction; *B*. forms parasitic in the adult stage, but with free-living larvae; *C*. forms entirely parasitic, the eggs not hatching until ingested by a suitable host; *D*. forms in which the adults are parasitic in a mammal and the

larvae parasitic in an invertebrate ; *E.* forms in which the adults are parasitic in the alimentary canal, the larvae encysting in the tissues of the host, and completing their development when the first host is eaten by another animal.

The *egg* is spherical or ovoid. In the parasitic forms it may pass out with the faeces, or, more rarely, hatch in the gut or even in the uterus of the parent worm (in the so-called " viviparous " forms). As a general rule, the larva emerging from the egg undergoes a series of moults before attaining sexual maturity.

Yorke and Maplestone (9) have divided the order into eight *superfamilies*, most of which contain species which concern us here.

In the superfamily TRICHUROIDEA there are two species which deserve mention. In this group the anterior end of the body is thread-like, and the oesophagus consists, for at least part of its length, of a delicate tube running through the centre of a chain of single cells.

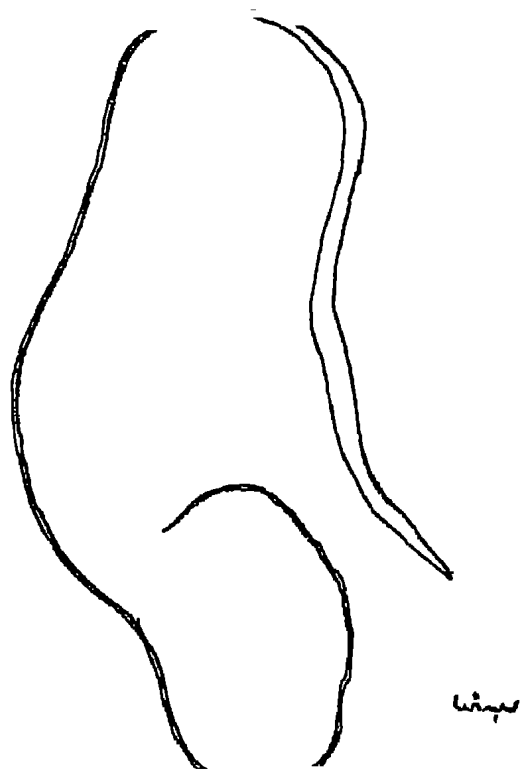

FIG. 5.—*Trichuris ovis.*

Trichuris ovis (*T. affinis*) is a worm from 5–7 cm. long, occurring in the small intestine and caecum of sheep and other ruminants. The anterior portion is very slender and much longer than the rest of the body, which is thick and contains the reproductive

organs. From its shape, this worm is often known as the "whipworm." A considerable portion of the anterior end (the free tip of the lash, so to speak) is imbedded in the mucous layer of the intestinal wall. The eggs are thick-walled and barrel-shaped, with a clear (? mucus) plug at either end. The development is not fully known. From what is known of the life-cycle of other species of the genus, it is probable that the eggs develop slowly outside the host; after several months they contain infective embryos (*T. trichura* of man). On being ingested by a suitable host, the embryo escapes into the gut, and burrows through the wall; entering the blood-stream and reaching the lungs (*T. vulpis* of the dog) (1) and finally the gut. As far as is known, *T. ovis* has but little effect on the host.

Trichinella spiralis (*Trichina spiralis*) is important in that it causes a grave disease of man in some countries. It is a small worm, the males being about 1·5 mm. in length, and the females 2–4 mm. The anterior portion is only slightly thinner than the posterior. The adult worms live in the alimentary canal of numerous animals. The eggs hatch within the female, and the larvae, penetrating through the gut wall, are carried by the lymph stream to various parts of the body. Here they become encysted; and when tissues containing these cysts are eaten by a suitable host, the larvae are liberated and attain the adult form. In many parts of the world pigs are very heavily parasitised (1), and it is from this source that man is infested. The pig itself becomes infested through eating rats having encysted larvae in their tissues, or through being fed with slaughter-house offal containing infected tissue from other pigs. The geographical distribution of this disease in man does not coincide with that of the disease in pigs; it is most common in those countries where a considerable quantity of raw or partly cooked meat is eaten.

The Ascarid worms (ASCAROIDEA) are fairly large and stout, with three prominent lips (or lobes) surrounding the mouth. The alimentary canal is simple. There is no mouth capsule, while in the male there is no genital bursa. The females are oviparous. Two genera belonging to the group concern us here—*Ascaris* and *Parascaris*.

Ascaris lumbricoides (*A. suum*, *A. suilla*) is a parasite of man and of the pig. The worm is white or faintly red, and pointed at both extremities ; females are 20–25 cm. in length, and males 15–17 cm. *A. ovis* (which Yorke thinks is probably identical with *lumbricoides*) is a rare

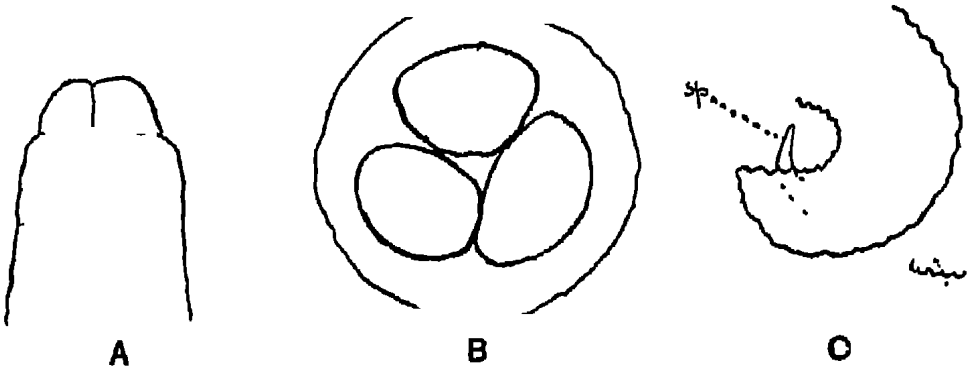

FIG. 6.—*Ascaris lumbricoides*. A, lateral view of anterior extremity. B, anterior view of anterior extremity. C, lateral view of posterior extremity of male (*sp*. spicule).

parasite of the sheep, and is found in the small intestine. *A. vitulorum* is a parasite of cattle. *Parascaris equorum* (*A. megalocephala*) differs slightly from typical *Ascaris ;* the male is 15–27 cm. and the female 18–37 cm. in length. It is a parasite of the horse and other equines.

Recent investigations have indicated the life-cycle to be rather more complex than was previously suspected. The eggs (passed out with the faeces) develop until an embryo is formed ; this takes from 3–4 days to several weeks, being dependent on the temperature, and also upon the species. When embryo-containing eggs are ingested by a suitable host, the embryo is liberated in the

small intestine. The larvae (the liberated embryos) penetrate through the gut wall into the blood vessels, and are carried by the blood-stream into the liver, in which serious tissue changes may arise from their presence. From the liver they are conveyed by the blood-stream to the lungs, where they escape into the air spaces, from whence they reach the pharynx and so re-enter the gut, to attain the adult condition. Ascarid infestation sets up a variety of disturbed conditions in the host. The changes in the liver have already been referred to. More important is the irritation set up in the lungs by the migrating larvae which often takes the form of a rapid and fatal pneumonia. The adult worms may cause very grave conditions, either through the blocking up of the alimentary canal, through damage to the gut wall, through a poisoning of the host by a toxic (poisonous) substance excreted by the worm, or through the deprivation of nutriment through its absorption by the worm.

A number of worms belonging to the superfamily STRONGYLOIDEA are of considerable economic importance. There is a copulatory bursa in the male. In many species there is a well-marked buccal capsule, which in some species is provided with teeth or with cutting plates. The oesophagus is more or less expanded posteriorly, but is without a definite spherical bulb. These worms are usually oviparous, but are occasionally viviparous.

Bunostomum trigonocephalus (*Monodontus trigonocephalus*) is a very common parasite of sheep, and is found in the small intestine. Jones (4) found somewhat over 40 per cent. of sheep examined in North Wales in 1924–25 to be infested with it. The male worm is 12–17 mm. and the female 19–26 mm. long. The vulva in the female is in the anterior part of the body. The eggs are passed out of the hosts' body with the faeces, and the infective larval stage is apparently attained in a few days.

The full life-history does not appear to have been satisfactorily worked out. Hall (3) remarks that the symptoms resulting from the presence of this worm have not received much attention. Allied forms (*Ancylostoma duodenale* and *Necator americana*) occurring in man, are responsible for grave anaemia and debility, which is brought about in two ways : by bleeding within the gut from the sites of bites inflicted by the worm, and through the action

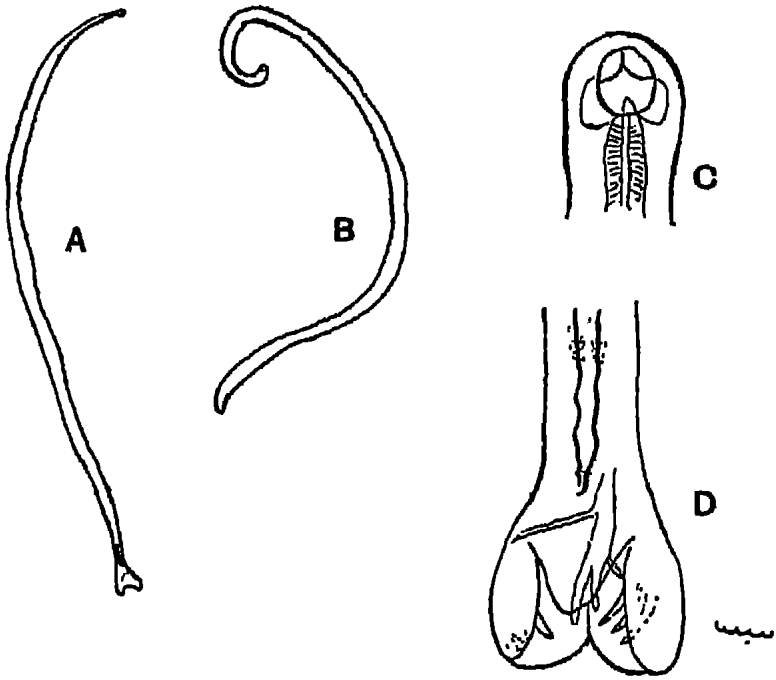

FIG. 7.—*Bunostomum trigonocephalum*. A, male; B, female; C, anterior end of male; D, posterior end of male.

on the blood of a toxin. There is some evidence that the effects of *B. trigonocephalus* on parasitised animals are similar.

Haemonchus contortus is parasitic in the fourth stomach of sheep. The males are 10–20 mm. and the females 18–30 mm. long. In the female the vulva is in the posterior portion of the body, and is covered with a conspicuous flap. The eggs pass out with the faeces and hatch at the

end of a period depending upon moisture and temperature. The larva undergoes moults resulting in an ensheathed larva ; this stage is very resistant to desiccation, etc. The larvae crawl up damp grass, etc., and are ingested by sheep while feeding. In the stomach maturity is attained in about three weeks, and eggs are produced about a week later. Infested sheep suffer at first from dullness and lack of thrift. After a time anaemia and oedema (" dropsy ") become noticeable ; the skin becomes pale, and the pendant portions of the body

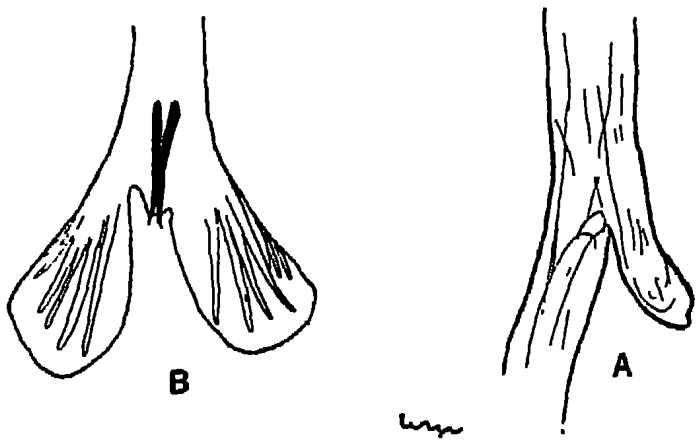

FIG. 8.—*Haemonchus contortus*. A, portion of female showing flap over vulva. B, genital bursa of male.

swell, and ultimately emaciation and death may supervene. Part of the damage is due to the fact that the worms bite the mucous layer of the stomach, leaving minute bleeding areas, and part probably to the production of toxins by the worm.

Oesophagostomum venulosum and other species of that genus are responsible for what is sometimes known as " nodular disease " in the intestines of sheep, hogs, etc. ; the species mentioned is parasitic in the sheep. The adult worms for the most part live free in the lumen of the gut. The eggs are passed out in the faeces, and,

according to some writers, hatch out rapidly, given favourable conditions, the larvae becoming infective after the first moult. When ingested by a suitable host, the larvae penetrate into the wall of the intestine, where they undergo a development over a period of several months ; these larvae give rise to the nodules characteristic of the infection. The nearly adult worms emerge from the nodules, and attain maturity in the intestine. The male of *Oe. venulosum* is 12–15 mm. in length ; the female is 18–24 mm. with the vulva very near the posterior end of the body.

The presence of these worms may cause no more than a slight debility, or they may bring about very marked wasting. To quote Hall, " The resultant loss cannot be accurately stated, but it occurs in terms of meat, wool, decreased growth, and poorer quality of animals, and from the fact that nodular intestines . . . are unfit for sausage casings " (3).

Chabertia ovina, a related species, occurs in the large intestine of the sheep and goat ; " this species appears to be comparatively harmless. Its food consists of the vegetable material in the contents of the . . . intestines. The buccal capsule is commonly found filled with such material " (7). The mouth is directed towards the ventral surface to some extent. The male is from 13–14 mm. long, and the females 17–20 mm. ; the vulva is near the anus.

Worms of the genus *Trichostrongylus* sometimes occur in enormous numbers in the fourth stomach and small intestine in ruminants. *T. vitrinus* and other species occur in Britain. They are very small worms, the males of *vitrinus* measuring 4–4·5 mm., and the females 5–6·5.

Ostertagia is another related genus, of which *O. trifurcata* and *O. circumcinta* have been recorded as British. The females of *trifurcata* measure 10–12 mm. They occur in the fourth stomach and small intestine.

The genus *Cooperia* is represented by *C. oncophora* and *C. curticei*. These again are similar in size and habitat to *Trichostrongylus*.

Nematodirus filicollis and *N. spathiger* are British. They are somewhat larger than those worms just mentioned, the males of *filicollis* being 10–15 mm. and the females 15–20 mm. long. They occur in the small intestine. Jones (4) recently found this to be one of the most abundant sheep parasites in North Wales, and Morgan (5) and Cameron (2) make similar observations for Mid-Wales and Scotland.

The life-histories of the above worms, as far as is known, appear to resemble that of *Haemonchus*. It should be mentioned that adverse symptoms (chiefly in sheep) have been ascribed to some of them. Their generally small size frequently causes them to be overlooked even during post-mortem examination, and when suspected, special methods must be resorted to in order to reveal their presence.

" Strongylosis " of the intestines of horse is ascribed to various species of the genera *Strongylus* and *Trichonema* (*Cylicostomum*). These are worms of moderate size. Some species are of very considerable economic importance, and may occur in great numbers. *Strongylus equinus* and *S. vulgaris* are among the most important. The life-histories are direct. The eggs pass out with the faeces, and after a period of development and one or more moults, the larvae become infective. Ingested by the horse the larvae penetrate through the intestinal wall into the blood-stream. The majority of workers believe that development to sexual maturity only occurs after some time has been spent in the blood vessels. During this period the presence of large numbers of larvae may give rise to very grave conditions (aneurysms) in infections with *S. vulgaris*. After moults the larvae again reach the wall of the intestine and form nodules in the mucous

layer, from whence they escape free into the intestine to attain sexual maturity. Apart from harm done by the larvae, the adults appear to feed upon tissue juices and blood obtained from the surface of the gut, with harmful results (similar to those caused by *Haemonchus*).

Syngamus trachea (*S. trachealis*), commonly known as the "gapeworm" or "forked-worm," is a very important parasite of fowls and other domestic birds. There is a definite mouth capsule present in both sexes, the margin of which is thickened to form a prominent rim. The females are from 5–20 mm. in length, and the vulva is in the anterior part of the body. The males are much smaller (2·6 mm.) and are permanently attached to the females at the site of the vulva. The living worms are red in colour. They are parasites of the respiratory system, occurring in the trachea and in the bronchial tubes also (according to some authors).

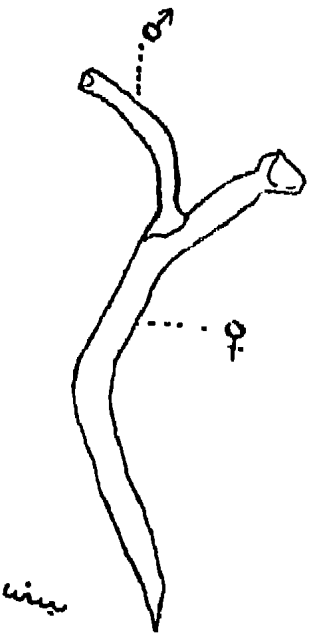

FIG. 9.—*Syngamus tracheae.*

Ortlepp (6) has recently investigated the life-history. He finds that, despite the fact that the male and female are permanently *in copula*, eggs can be laid. The eggs reach the exterior by being coughed out directly, or by passing through the alimentary canal. Under favourable conditions they take about a week to hatch, and the larva undergoes a single moult before attaining the infective stage. These second stage larvae are generally enclosed in a sheath (the cast skin of the previous stage). They cannot penetrate the skin (hence infection must take place through the mouth) and will not stand desiccation. Ingested by the host, the larvae migrate to the

lungs, from which they have been recovered as early as twenty hours after the infesting meal; the route followed has not been determined, but Ortlepp believes that it will be "found to be *viâ* the blood-stream as in the case with Ascarid . . . larvae." In the lungs the larvae undergo two further moults, attaining the final larval stage in about five days. After this the larvae copulate, and migrate to the trachea, where sexual maturity is reached in from ten to eleven days.

While no intermediate host is required, there is a certain amount of evidence which indicates that birds can become infected by eating earthworms which have ingested *Syngamus* eggs.

Various wild birds play a considerable part in the dissemination of *Syngamus*, since infection is very common in several species.

Various species belonging to the genera *Dictyocaulus* and *Synthetocaulus* are parasitic in the lungs and air passages of various mammals. *Dictyocaulus filaria* is found in sheep and goats; the female is from 50–100 mm. in length, and the male 30–80 mm. There is no buccal capsule. *D. viviparus* (*D. micrurus*) is a worm found in cattle. Males measure 35–40 mm. and females 60–80 mm. Both of these worms are the cause of "husk." *Synthetocaulus rufescens* occurs occasionally in sheep. These worms are popularly called "threadworms" from their likeness to pieces of cotton thread.

The life-histories of these worms does not appear to have been completely worked out as yet, various authors giving somewhat contradictory accounts. According to some the development is simple, the larva emerging from the egg becoming infective after one or two moults, while others state that a free-living sexual generation occurs, and that the larvae produced by this generation are infective to the host. It appears probable that the infective larvae (however this stage may be reached) is

either ingested by the host on herbage or fodder, or may be inhaled into the lungs with dust. There is no evidence as to the route by which the lungs are reached. Within the lungs and the air vessels the larvae develop to the adult stage ; the eggs are probably carried up to the pharynx in the exudates from the lungs, and from thence they may be coughed out, or carried with the food to the gut.

The presence of the worms gives rise to a bronchial catarrh in mild cases, and in more serious ones to a grave broncho-pneumonia, which may be complicated by bacterial infection.

In the superfamily OXYUROIDEA there is a definite bulbar enlargement of the posterior end of the oesophagus. There is no genital bursa in the male. The caudal (posterior) end of the female worm is usually prolonged into a finely pointed tail.

Oxyuris equi is a parasite of the horse. The adult worms are whitish and generally somewhat curved ; the male is from 5–12 mm. and the female 40–150 mm. in length. In the female the body narrows somewhat suddenly behind the anus, and is more or less prolonged into a narrow tail, the length of which varies according to the age of the worm (this has led some workers to divide the species into two or more separate species based on the length of the tail). The females are often termed " whipworms," but may readily be distinguished from the true whipworm by being free in the gut, while the nature of the thin portion can readily be detected under the microscope.

The adult worms and the larvae are found in the upper part of the gut ; the fertilised females wander down to the anus and lay their eggs on the skin surrounding it. As in the case of *O. vermicularis* (now placed in the genus *Enterobius*) of man, the eggs contain an embryo when laid which takes a very considerable period to develop

into the infective larval stage. After a few days the eggs drop off the skin, and reaching the ground are scattered about, fouling the pasture, or the fodder in the stable. The development within the host has not been elucidated completely.

The worms do not cause much trouble while in the gut, so far as is known ; but the movements of the females around the anus produce a grave irritation which may produce loss of condition.

Heterakis vesicularis and other species occur in fowls and some other birds. There is a distinct bulb in the oesophagus. In *H. vesicularis* the male is 8–10 mm. and the female 11–13 mm. in length. As far as is known, the eggs require some time to become infective, and the larvae develop directly into the adult, without a migration through the tissues of the host.

As regards the treatment of nematode infestation in general, little can be said. Various anthelminthic drugs are employed, which should only be administered under veterinary supervision. In this connection correct identification of the parasites is of importance. General hygienic measures are indicated as the best preventive ; the avoidance of infested pastures (which may frequently be cleared by subsequent drainage and cropping) ; ensuring a supply of uncontaminated drinking water ; and, if possible, the isolation of infested or suspected animals, are obvious but necessary measures.

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CHAPTER VI

PARASITIC ARTHROPODA—ACARINA (MITES AND TICKS)

THE Phylum ARTHROPODA comprises an enormous assemblage of forms, many of which are of the very greatest importance to the agriculturist. Taken as a whole, the Phylum includes forms as diverse as shrimps, crabs, and barnacles (CRUSTACEA), scorpions, spiders, mites, ticks, and harvest-men (ARACHNIDA), millipedes (DIPLOPODA), centipedes (CHILOPODA), the true insects (HEXAPODA), and many others.

Collectively, they show the following characters: The body is made up of a linear series of rings or segments, some of which bear paired jointed appendages, and have an external skeleton, consisting largely of a peculiar substance known as chitin (1). There is a simple alimentary canal divisible into fore-, mid-, and hind-gut; the nervous system consists of a dorsal "brain" and a double ventral chain of ganglia; the circulatory system is ill-defined (a dorsal heart being present), but communicates freely with the body spaces. The sexes are separate.

Certain of the classes do not concern us at all, but the Mites, Ticks, and Insects must be considered in some detail. The first two are included in the class ARACHNIDA. They are terrestrial and exhibit a considerable diversity of organisation, ranging from the simple mites to the much more highly specialised spiders and others. The body is either undifferentiated or is divided into two regions, the *cephalothorax* and *abdomen*. When there is

differentiation the cephalothorax is unsegmented and bears two pairs of mouth-appendages, simple eyes, and four pairs of legs. The abdomen is without legs, and may or may not be segmented. Respiration is effected in various ways, and may be *tracheal*, that is, by means of a special series of openings known as *stigmata* or *spiracles* which admit air to an intricate branching series of respiratory tubules, the *tracheae ;* or by what are known as " book-lungs," a series of pockets or folds of the integument closely applied to one another as in spiders. In many mites, however, neither of these devices exist, and respiration is effected through the general body surface. The sexes are separate, the females being generally oviparous. Growth is usually gradual, and without marked stages, although some (as in the Ticks) undergo moults which disclose considerable changes.

The order ACARINA contains the Mites and Ticks. In these the ova hatch out into larvae, which usually possess six legs and show no definite sexual characters ; a further developmental stage with eight legs, the *nymph*, is next attained, and finally sexual maturity is acquired. The mouth parts are modified into a beak-like structure adapted for piercing and sucking. The majority of ACARINA are parasitic, and many are of very small size. They are divided into a considerable number of families.

The TROMBIDIIDAE are mites with soft integuments and biting mouth parts, the larvae being parasitic and the adults free-living. The larvae are sometimes the cause of skin eruptions and severe irritation in man and in birds. They occur amongst vegetation in summer and autumn, whence they pass on to their hosts. The name *Trombicula autumnalis* has recently been given to an abundant form (2) the larvae of which had previously been known as *Leptus autumnalis*. A Japanese species of *Trombicula* is known to be the carriers of Kedani or river fever. It is probable that their later stages will be found

beneath the surface of the ground or in the nests of wild rodents.

The DERMANYSSIDAE are parasitic upon birds, and one species is of economic importance. *Dermanyssus gallinae* is a nocturnal species frequently occurring in great numbers in fowl-houses, etc., especially in those which are dark, damp, and ill-kept. Here they lurk in crevices, etc., attacking the birds by night. They feed for a short period and then return to shelter, so that although the birds may be noticeably impoverished, the cause may not be suspected. Thorough cleansing and disinfection are called for, together with the provision of modern housing.

The SARCOPTIDAE furnish numerous harmful species, which bring about the condition known as " scabies " of mammals and birds. The specific name, *scabiei*, is now taken as comprising all the forms infesting man and the domestic animals. These forms show no reliable morphological distinctions among themselves; the differences would appear to be biological only, and the varieties can only be determined by their respective host relationships, thus the form occurring on man is known as *Sarcoptes scabiei* var. *hominis*, that of the horse var. *equi*, of the sheep var. *ovis*, etc. At times they produce serious symptoms, more particularly during autumn and winter, which is believed by Pillers to be largely due to an effort on the part of the mites to obtain a suitable amount of warmth for their activities, since they are very sensitive to temperature (7). Another species is *Cnemidocoptes mutans*, the cause of " scaly leg " in fowls and related birds. The mites burrow under the scales of the foot and leg, setting up an irritation which leads to an exudation of serum which accumulates, forming thick, crusty deposits, and causing lameness if neglected. A further species, *C. laevis* var. *gallinae*, is found chiefly upon the head, neck, etc., causing the birds to pull out the feathers,

" depluming scabies." In scaly leg, the treatment is to soak the legs, remove the scabs as far as possible, and apply ointments of creosote and lard, or sulpur and vaseline (7).

The genus *Psoroptes* furnishes a series of troublesome species attacking live stock, including *P. communis*. The species has varieties found on the horse and sheep which are by some considered as distinct species. *P. communis* var. *ovis* is the cause of the well-known " sheep scab." This condition has necessitated much legislation, and is a worry to flockmasters, in many parts of the world, and at times still assumes serious proportions in Great Britain. The trouble usually arises from certain of the rougher areas where the mites are never completely eradicated, and whence the spread may be rapid. The rapidity with which Acari breed is very great, and it is estimated that the progeny of one burrowing female mite will reach six generations and 1,500,000 descendants in ninety days (10). The presence of the mites in the skin sets up intense irritation, and a serous fluid exudes which dries to form yellowish scabs which increase and coalesce, forming irregular patches. Condition is lost, the fleece becomes torn through rubbing and scratching, and in extreme and neglected cases death may follow.

Control is by dipping with various fluids containing sulphur, arsenic, or cresol, at intervals of seven to fourteen days, twice or thrice being needed to eradicate the parasite. Full instructions are issued with the materials, and should be most carefully carried out.

Two other forms, *S. scabei* var. *ovis*, which causes the condition known as " head mange," and *Chorioptes ovis*, the cause of " foot mange," must be mentioned. Neither of these is as serious as common scab, although the former may cause trouble now and again; the latter appears to be of but slight importance. The genus *Chorioptes*, however, contains several other species attacking the

horse, ox, goat, and rabbit. Ear mange in the ferret is due to *Otodectes furonis*, whilst *O. felis* attacks the ears of cats. Species of *Notoëdrus* also attack cat, rabbit, and others.

The family DEMODICIDAE contains wormlike mites, certain of which are said to give rise to troublesome affections of the skin, whilst others are said to be harmless. These mites live imbedded in the skin, and give rise to " demodectic mange " in man, cats, horses, cattle, pigs, and goats (3). It is pointed out by Pillers that several of these conditions may occur simultaneously, skin scrapings from affected animals disclosing on examination the presence of one or more species possibly belonging to different families : such cases are known as " multiple " or " poly-infections."

The various " mange," " scabies," and " itch " conditions set up by heavy infestation of the various mites which have just been described are frequently difficult to treat. Isolation and treatment of suspected and initial cases in " quarantine " is an obvious but frequently neglected precaution. The treatment of severe infestation usually calls for veterinary advice, but generally takes the forms of removal of hair, and of accumulations of crusts and filth, the cleansing of the affected part, and the application of various remedial substances in the form of dips, lotions, or ointments.

Yet another family, the TARSONEMIDAE, furnishes a species of great economic importance, namely, *Acarapis woodi* (formerly placed in the genus *Tarsonemus*), which is now recognised as the cause of a disease of honey bees formerly called " Isle of Wight," but now known as " Acarine disease." All types of adult bees are liable to infestation, and such bees become unable to fly, in which stage they are called " crawlers." This condition is due to the invasion of the thoracic tracheae (breathing tubes) of the bee by the mites, which are true parasites, and feed

and breed in the regions indicated, thus " blocking up the air tubes, restricting the supply of oxygen, and causing a deterioration of tissue " (8). The mites feed on the blood of the bee and also foul the tracheae inhabited. The remaining pairs of tracheae in the bee are too small to admit of the entry of the mite. This disease is spread from bee to bee outside the hive by infested bees which are still able to forage ; by queens or drones ; or by " robbing " from a weakened stock in a diseased hive. Within the hive, the adult female mites readily leave the sick bees and pass to others, even the queen becoming infested. During past years enormous numbers of bees died throughout the country, and the bee industry fell away in an alarming manner. This has now been remedied, to a very considerable extent, through restocking from clean sources and by an understanding of the cause and methods of infestation, and its avoidance. The application of up-to-date methods of management, hygiene, and breeding can also do much to combat this disease.

Ticks are large and specialised forms of ACARINA, placed in the superfamily IXODOIDEA, which is again divided into two subfamilies, the ARGASIDAE and the IXODIDAE.

Ticks have a very wide distribution, and are of great economic importance, not only as parasitic blood-suckers, but as the vectors and transmitters of a number of the most serious blood diseases, due to various parasitic Protozoa (some of which have already been mentioned).

Whilst exhibiting in the main the general characteristics of the order, ticks are larger and show specialised features, such as the *capitulum*, which projects forward from the " head " region. This is made up of a hard basal ring called the *basiscapituli* ; a median chitnous structure beset with recurved teeth, the *hypostome ;* and a laterally placed pair of appendages known as

chelicerae. These parts constitute what may be termed a "beak," which serve for the penetration of the tissues of the host, and as a most efficient anchorage during the blood-sucking period. In addition, jointed structures, the *palpi*, are situated on either side of the hypostome. In the IXODIDAE a hard dorsal shield or *scutum* is present, which in the male covers the entire body, whilst in the female it forms a well-marked area on the anterior and dorsal aspect, whilst the rest of the body is capable of a remarkable degree of distention during feeding. In the ARGASIDAE this scutum is absent, and the body is protected by a more or less uniform leathery integument (5). Many other differences also exist. In all, a pair of respiratory openings are situated one on either side of the body. The ARGASIDAE occur chiefly in Asia, Africa, and Australia, and in the warmer regions of Europe and America, and attack birds and bats, and also man; they are largely nocturnal, and seem to prefer dry conditions. *Argas reflexus* has been recorded as attacking pigeons in Britain. It used to be quite common in the towers of Canterbury Cathedral, and Dr. L. E. Robinson informs us that living specimens were obtained there in 1908. *A. vespertilionis* is found on bats in this country.

The IXODIDAE, on the other hand, are found almost all over the world; and all are blood-sucking parasites of reptiles, birds, and mammals, including man. A number of species occur in the British Isles. Chief amongst these is the very common cattle tick, *Ixodes ricinus*. This species is oval in outline, yellowish-red, brown, or grey in colour, and may attain a size of 11 by 7 mm. when fully fed (engorged). The male is dark red-brown, and about 2·4 mm. in length. This tick occurs in great numbers in the rougher, ill-drained, and more wooded parts of the country, attacking cattle, sheep, and, to a less extent, horses, dogs, foxes, cats and a large number of other animals, whilst the younger stages

PLATE III

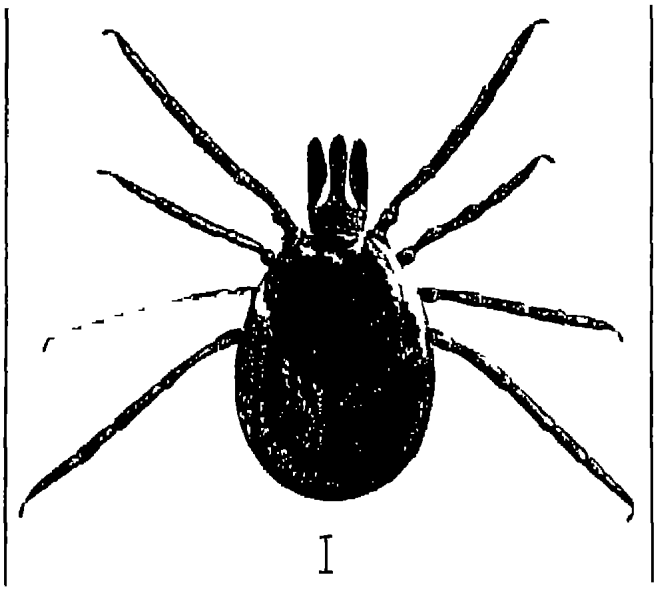

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FIG. 1 —*Ixodes ricinus*. ♀ dorsum, × 12

FIG 2 —*I. ricinus*. ♂ venter.

[From Nuttall and Warburton]

(larvae and nymphs) may even attach themselves to man. In the adult stages both males and females are present on the host, where pairing frequently occurs, females being more abundant than males.

When fertilised and fully engorged, the females release their hold and fall to the ground, where oviposition takes place. The females are stated to shelter beneath surface vegetation or stones, or to burrow into loose soil, where they lie quietly for days or weeks prior to laying eggs (6). This is largely influenced by temperature, being retarded by cold. The eggs are very numerous, ranging from hundreds to a thousand or more. At suitable temperatures six-legged larvae hatch from the eggs, ascend the herbage, and await an opportunity to attach themselves to a passing host animal, to obtain the necessary feed of blood. This accomplished, the replete larva releases its hold, and undergoes a moult on the ground. The nymph, which now appears, possess a pair of spiracles and four pairs of legs; after the cuticle has hardened, this stage again attacks a host animal, to drop off when replete, after a period of 3–5 days. The adult develops within the nymphal skin, and emerges after an interval of weeks or months. The sexual organs do not become fully developed in the female until she has again sucked blood. Three hosts are thus necessary for feeding purposes during the life-cycle, which may be much prolonged by the temporary absence of suitable animals as also by adverse weather conditions. Ticks are soon killed by desiccation (drought), but can survive cold, and may remain unfed for long periods: larvae up to 19 months, nymphs 18 months, and adults for 27 months. The life-cycle may be completed, all conditions being favourable, in about six months, or may be prolonged to three years (5).

The transmission of the blood parasite, *Babesia bovis*, the cause of the well-known "redwater" of cattle, by

Ixodes ricinus is a well-established fact. Cattle have been infected experimentally by exposing them to the bites of larval ticks which have developed from eggs laid by ticks collected from infected animals (11). Another, and in Great Britain much more local species, *Haemaphysalis punctata*, has also been proved to be able to transmit infection (9), but *I. ricinus* is the normal vector. Symptoms appear in from 5–28 days after exposure to infection, and two or three days later, the redwater condition sets in. The redwater symptoms are due to the destruction of red blood-corpuscles by the parasite (*B. bovis*) at the time of shizogony; the colouring matter (haemoglobin) being set free in the blood, and excreted in the urine, which is, in consequence, tinted light to dark red according to the severity of the attack.

The disease is naturally limited to those areas where ticks occur, and have become infected with *Babesia bovis*. This is brought about through their sucking the blood of cattle suffering from the disease, or which are still infected with the parasites though not showing active symptoms.

Various suggestions have been put forward as to tick eradication and purification, of which the chief are: (*a*) "Starving out," which is practised abroad, but, being a somewhat lengthy process, is not suited to British agricultural practice. (*b*) The eradication of ticks from the land by improvement, such as drainage, cutting and clearing bushes, ferns, etc., and the elimination of coarse herbage by manuring and cultivation. (*c*) The reduction or even the elimination of ticks by means of grazing sheep (which are not susceptible to redwater) before cattle are sent to pasture, the sheep being dipped at intervals in order to kill the ticks collected (4). This method further leads (without dipping) to the gradual purification of the ticks, with a corresponding lowering of the number of cases in cattle subsequently grazed. The writers have

seen numerous instances of this in Wales. (*d*) The disease is seasonal to a considerable degree, and redwater cases tend to occur in two well-marked periods—spring and early summer, and again in autumn ; cattle may obviously be replaced by sheep during these periods. (*e*) Farmers taking over infested grazing should be particularly careful, since, should their cattle not have been rendered resistant in any way, severe outbreaks attended by heavy loss are to be expected. (*f*) Herds that have long grazed infected land and are derived from cattle reared thereon, tend to have a partial or complete immunity from the disease, and cattle added to such herds should be selected whenever possible from similar herds in the vicinity. Serious and persistent losses may follow non-observance of this precaution. It follows equally that (*g*) farmers whose land is free from ticks should see to it that ticks are not imported on cattle brought on to the farm from elsewhere ; and that if ticks are present on their land cattle from redwater farms should not be purchased, or taken in to graze, as such may harbour the parasite and so introduce the disease.

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CHAPTER VII

PARASITIC ARTHROPODA—HEXAPODA (INSECTS)

THE Class HEXAPODA (called by some writers INSECTA) contains the true insects.

In the ARACHNIDA, described in the last chapter, the division of the body into two regions, the cephalothorax and abdomen, was noted; but in the insects this subdivision is carried further, and three distinct regions —the head, the thorax, and the abdomen—can be recognised.

The head bears eyes, simple or compound (both of which may be present); sensory organs—the antennae; and mouth-parts, which are typically adapted for biting, but which may be modified for piercing or sucking.

The thorax is composed of three of the body segments, named the *prothorax*, *mesothorax*, and *metathorax* respectively, which are more or less firmly joined together, but in any case are distinguishable by the fact that each bears a pair of legs. Wings, when present, are borne dorsally by the second and third of these segments. The legs are divided into the following parts, *coxa*, *trochanter*, *femur*, *tibia*, and *tarsus* (or foot); and the wings are typically two pairs of membranous appendages which originate as outgrowths from the body wall. In some fossil insects, a third pair of wings was borne on the prothorax.

The abdomen consists of a series of similar segments, which are without appendages, except for those at the extremity of the body, where much modification may

also exist connected with organs of sex, etc. The number of segments of which the abdomen appears to be composed therefore varies greatly in different insects, and Comstock (1) points out that all intergrades exist between three or four, and eleven.

The main features of the internal anatomy have already been detailed (see ARTHROPODA). It must, however, be noted that the insect *exoskeleton* (a hard supporting structure derived from the underlying cells) is made up of a remarkably effective substance named *chitin*, which is at one and the same time firm, light, and durable. Chitin also occurs in certain inwardly directed structures (the *endoskeleton*), and forms the lining of the fore- and hind-gut. The very numerous muscles are attached either to the exoskeleton or to the endoskeletal processes.

The mouth-parts of insects are of great importance, and show much variation and modification, being adapted to the equally varied modes of life and feeding. In the main, two chief types can be recognised, those adapted for biting—whether the chewing of vegetable matter or the seizing and tearing of prey—and those formed for sucking: in certain cases both these functions are combined. Basally and typically the mouth-parts consist of the *labrum*, or upper lip; the *labium*, or lower lip; an upper pair of jaws termed the *mandibles;* and the *maxillae*, or lower pair of jaws. There is also a median tongue-like structure, the *hypopharynx*. From this basal condition there have arisen, by modification, such remarkable types as the butterfly, house-fly, horse-fly, or mosquito, and bug proboscides. In some extreme cases the mouth-parts have atrophied or ceased to function.

Alimentary system.—This is a tube of varying length, extending from one end of the body to the other, and divisible into fore-, mid-, and hind-guts. Both the fore and hind sections originate as invaginations (or in-pushings) of the body wall, and are in consequence lined

with chitin. The fore-gut comprises the *pharynx*, immediately behind the mouth; the *oesophagus;* a "crop" which is a dilated portion of the oesophagus, present in many insects; and a *proventriculus* or "gizzard"—more particularly in insects that feed upon hard substances. *Salivary glands* are present, which open near the mouth. The mid-gut has a variable structure, and may be sac-like or coiled, whilst diverticula or caeca (blind tubes or sacs) may be present. The hind-gut usually shows three regions: the *small* and *large intestines* and the *rectum.* The *Malpighian vessels* vary in number; they are slender tubes opening into the fore-part of the hind-gut, and are excretory in function. A prominent feature on dissection, more especially in larvae, is the fat body, which stores nutriment.

Respiratory System.—This consists, in most insects, of a complex network of air-tubes, the *trachcae.* Air enters this system by means of small, paired, laterally placed openings, called spiracles or stigmata, the usual number being ten pairs, two pairs being thoracic, and the remainder abdominal in location. As in other features, great variation exists, and in some COLLEMBOLA they are missing, respiration being cutaneous. The spiracles open into the tracheae, which divide and subdivide into an intimately ramified system, the ultimate twigs of which are termed *tracheoles*, and are of extreme tenuity. In many winged insects there are expansions of the tracheae which are termed *airsacs.* This air system is most efficient in its functioning, and with the airsacs renders the insect body very light. The inmost layer of the tracheal wall is chitinous, and is strengthened by spiral thickenings. The high efficiency of chitin, tracheal system, and flight operating together may be considered as among the chief factors contributing to the remarkable ubiquity and success of the Hexapod type.

The *Circulatory System* is largely an open one, there being only a single closed organ which is situated dorsally, and is often called the " heart." The greater part of the circulation takes place in the cavities of the body and of the appendages (1). The blood, which may be colourless or tinted, thus bathes all the internal organs.

The *Nervous System* comprises a " brain," a mass of *ganglia* or nerve centres, situated in the head above the oesophagus ; another ganglionic mass below the oesophagus ; and a double series of ganglia lying along the floor of the body cavity, and connected by nerve fibres. Nerves radiate from these centres to all parts of the body.

Sense organs are present in many forms, those of sight being eyes and *ocelli*, the former being compound and in the higher insects both large and efficient ; the latter simply single eye-spots. Organs of touch, hearing, taste, and smell are also recognised, being represented by various pits, hairs, cones, pores, etc., situated on the *antennae* (a pair of mobile jointed appendages situated on the head) and other parts of the body.

The Reproductive Organs.—In insects the sexes are normally distinct. In the female (♀) the ova (eggs) are developed in a pair of *ovaries*, from each of which a tube, the *oviduct*, leads to the external sex organs. An *ovipositor*, or special structure for placing the eggs in a suitable location, is frequently present. In the male (♂) the essential organs are a pair of *testes*, in which the spermatozoa are developed and a tube, the *vas deferens*, leading from each to the exterior. The reproductive orifice is in each case on the ventral side and near the end of the abdomen. In both sexes certain other accessory glands exist. In addition to the above-mentioned organs, many insects show what are termed " secondary sexual characters," which are exemplified in such external features as size, colour, antennal or eye characters, etc.

The wings, which play such an important part in the adult life of the majority of insects, are described in detail by Comstock (2), who has paid much attention to their study. They are typically two pairs of membranous appendages, borne by the meso- and metathoracic segments, and studies of their development show that they arise as sac-like folds of the body wall, although this is not obvious when they are fully developed. The upper and lower walls become adherent, and finally present the appearance of a single delicate membrane. "Along certain lines," says Comstock, "the walls remain separate, and are thickened, forming the firmer framework of the wing. These thickened and hollow lines are termed 'veins of the wing,' and their arrangement is described the venation." The spaces bounded by the veins are called cells, and the varying arrangements of cells and veins are much used in the description and classification of insects. The wings themselves vary greatly, in the different orders of insects, whilst in several they are entirely absent. This condition may either be primitive, wings never having been evolved, as in the COLLEMBOLA (Springtails) and others, or can be accounted for by loss through disuse or degeneration as in many parasites, such as lice. Wings may be present in one sex only, and become reduced or lost in the other. They may be membranous and bare, or hairy, or clothed with scales.

Many insects during their lives pass through remarkable periods of change of form, which are most marked in the more highly specialised orders. In others, less specialised, the changes are more gradual, and less obvious. In a few, and comparatively rare cases, the young are produced alive, either through an unusually prolonged retention of the egg within the body of the female, or by *parthenogenesis* (which is reproduction without previous fertilisation). This may occur in special instances, or during certain seasons of the year,

whilst instances are recorded where males are produced at rare intervals or are quite unknown. Normally, however, fertilised eggs are laid, varying greatly in number and form. Hatching follows after a period of development which may be rapid, or prolonged owing to weather conditions, etc. From the matured egg emerges a *larva*, which in the less specialised forms does not differ greatly in form from the adult insect, and which undergoes a progressive series of moults or *ecdyses*, each of which brings it nearer to maturity. These moults are necessary owing to the chitinous covering rapidly becoming too small through growth; this difficulty is overcome by the periodic shedding of the old covering. The new cuticle remains elastic for a time, and so allows for expansion, until it in turn becomes chitinised and rigid. The term *instar* is applied to the form of the insect between each ecdysis. Such a development is termed a *gradual* or *incomplete metamorphosis*. In the higher insects, the hatching egg discloses a well-marked larva, which differs markedly in form from the adult. It is in the larval stage that growth takes place; moults occur from time to time, the last one disclosing the *pupa*. During this stage (the pupa) very remarkable and profound changes occur, resulting finally in the appearance of the adult and mature insect, or *imago*. Such a development is known as a *complete metamorphosis*. Pairing usually takes place soon after hatching.

About 450,000 species of insect have been described, and the total must greatly exceed even these extraordinary figures. Insects are found practically everywhere on the globe, their ubiquity being only equalled by their adaptability. Imms (3) states that they range in size from a length of ·25 mm. to 260 mm., whilst one of the LEPIDOPTERA attains a wing expanse of 280 mm. Insect activities include plant feeding—probably 50 per cent. of all species; scavenging—living on dead animal

matter and plant refuse; parasitism—either upon other insects or upon vertebrates, etc. It has been well said that insects are the predominant zoological group of the present day, and the present era has been termed the "Age of Insects." Some insects are undoubtedly a most serious menace to man and his activities, and frequently his skill and ingenuity are taxed to the utmost in combating their attacks upon his crops, his live-stock, his stores, and his productions in general.

The classification adopted here is that of Imms (3), who recognises twenty-three orders.

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CHAPTER VIII

PARASITIC HEXAPODA—ANOPLURA (LICE)

MOST authorities classify the Lice into two orders—the MALLOPHAGA (Biting and Bird Lice) and the ANOPLURA (Sucking Lice). A recent authoritative work, however (4), places all in the one order ANOPLURA (with two sub-orders): and this system will be followed here.

Lice may be described as small flattened apterous (wingless) insects living as ectoparasites of birds and mammals. The antennae are short, and the eyes reduced or absent. The mouth-parts are highly modified, and adapted for biting or piercing. Legs short, the feet one or two jointed, and adapted for clinging to the host. Metamorphosis wanting.

Suborder I., MALLOPHAGA, contains the bird lice, which are for the most part external parasites of birds although a few are found on mammals. The mouth-parts are of the modified *biting* type. All are small, flattened, and active, and do not suck blood directly, but live on hair or feather fragments and other skin products; their food thus consists of dry and often dead matter which they bite off with their strong, sharp-edged mandibles. It is stated, however, that they will obtain blood from a wound. The majority of species occur on wild birds, but domestic poultry are liable to infestation by a number of species, some of which are very injurious, especially on chickens and young birds, which may be infested from the brooding birds, almost as soon as hatched. Injury is largely through irritation. In

time to time, and dusting prepared nests with fresh insect powder (pyrethrum) is recommended, as is also the use of fine wood shavings instead of straw. Pyrethrum may also be added to the dust bath (1).

Sheep are sometimes affected by *Trichodectes ovis* (*sphaerocephalus*), often called the "Wool Louse" or "Red Louse." This is not usually an abundant pest in Great Britain, but serious infestations do occur, more especially on animals in poor condition. Sheep that are heavily infested are unable to settle or feed in peace, but spend considerable time in rubbing and scratching, which results in broken fleeces (5). This louse is light red or whitish in colour, with iron-red bands on the thorax and abdomen; the head is broad, and the legs short, stout, and hooked; it is usually found close to the skin, and is very active; the female is larger than the male. The eggs, which are attached to the wool-fibres by means of a sticky substance, are ovoid in form and pale in colour. Control can be effected by a thorough course of dipping, arsenicals being particularly effective. It is important that such spots as the inside of the ear, etc., are carefully treated.

Suborder II. The SIPHUNCULATA are lice in which the mouth-parts are modified for *piercing* and *sucking*, and are capable of being retracted within the head when not in use. They are blood-sucking parasites of mammals, a number occurring on man, and his domestic animals.

The family PEDICULIDAE contains several human parasites. The best known of these is *Pediculus humanus*, the common louse of man, which exists in at least two races, known as *P. humanus capitis* (the head louse), and *P. humanus corporis* (or *vestimentis*) (the body louse). Both are associated with unhygienic conditions, and are the proved carriers of typhus, trench, and European relapsing fevers. A good account is given by Waterston (7).

The family HAEMATOPINIDAE includes a number of pests of live-stock. *Haematopinus asini* is found on the horse and the ass; *H. eurysternus* on cattle, and *H. suis* on the pig. The last two are frequently met with on the farm. In this family eyes are lacking, the antennae are five-jointed, and the tibia has a thumb-like process opposing the claw.

Haematopinus suis is the largest louse affecting domestic animals, and although the pig is its only host, it will bite man. If neglected it will increase with great rapidity, and soon cause an unthrifty condition. It is usually found in the folds of the neck, etc., inside and at the base of the ears, the inside of the legs, the flank, and in smaller numbers on the back. The eggs are white, and are from 1·5–1·75 mm. in length; they are laid one at a time on the bristles, to which they are attached by a clear cement; the ventral surface is attached to the bristle. Hatching takes place in 12–15 days, the operculum opening away from the bristle. There are three moults. Sexual maturity is attained on the third day after the final moult, and the duration of the life-cycle is stated to be 29–33 days. The unfed louse is of a greyish colour and much wrinkled; when fed it has a smooth and shining appearance. The abdomen of the male is shorter than that of the female and appears considerably broader, whilst that of the female appears to be more slender (3).

The head is long, narrow, and cone-shaped; the abdomen is rather broader than long, and has a distinctly segmented border. The thorax is brownish-red in colour, and the abdomen grey. The female measures 5 mm. in length, and the male 4 mm.

These lice are very active blood-suckers, and if abundant the skin soon becomes covered with papules and scales. Irritation is severe, and causes violent scratching and a constant restlessness which interferes

PLATE V.

FIG. 1. — *Haematopinus eurysternus.* Female. 25.

FIG 2. — *H. eurysternus* Eggs on hair. (The upper egg was ripe and burst during the process of mounting. The black curved band in it is an air-bubble. Immediately below is the young louse.) 30.

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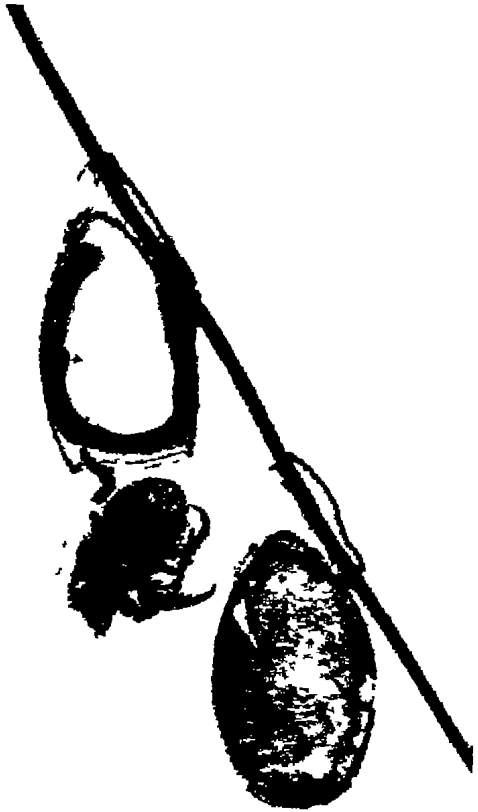

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seriously with growth and fattening, whilst young pigs have been known to succumb (6).

Other forms infest the dog, cat, etc., but the life-histories all bear a considerable similarity.

The control calls for correct sanitation, housing, and care of animals; segregation and treatment of suspects before introduction to parasite-free herds, etc. Nicotine washes, tobacco powder, creolin, paraffin, linseed and other oils, lard and sulphur, mercuric ointment, etc., are all commended and used; of late, sodium fluoride and extracts of derris are proving of value. Prior to treatment, it will in many instances be necessary to resort to clipping where long, dirty, or matted hair will impede action. All eradication methods should be repeated at least three times at intervals of 8–10 days in order to destroy the young forms before they can attain maturity.

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CHAPTER IX

PARASITIC HEXAPODA—DIPTERA (FLIES)

THIS order is one of the most important from the economic standpoint, and also one of the largest, some 50,000 species having been described, about 3,000 being British.

The adult insects are amongst those most readily recognised. Flies possess only one pair of fully developed wings—the front pair—which are membranous in structure. The hind pair are greatly reduced, and are represented only by vestiges known as *halteres*. The mouth-parts are also very highly modified, and usually form a trunk-like process or *proboscis* adapted for sucking; sometimes they are adapted for piercing, and sucking blood. The metamorphosis is very well marked; the larva is usually a legless "maggot," the head being greatly reduced; the pupa is either free or enclosed in the hardened cuticle of the larva, known as the *puparium*.

Flies are amongst the most highly specialised of all insects; many visit flowers, others favour garbage, whilst a considerable number suck blood—more especially the females: some of these concern us here, as also do a group with parasitic larvae. Other points may be briefly referred to. The head is usually fairly large, and remarkably mobile, the greater part of it being occupied by the large compound eyes. In the majority of cases these large eyes meet frontally in the male (*holoptic*), but are separated in the female (*dichoptic*). The antennae consist in some instances of a series of similar

joints, but are frequently of peculiar form, and then comprise two or three stout basal joints, bearing a more slender terminal portion, which may be jointed (*style*) or bristle-like (*arista*), which last is frequently situated on the dorsal surface of the joint bearing it.

The arrangement of the body bristles (hairs) of flies is of considerable importance, and their study is termed *chaetotaxy*.

The range of habits shown by fly larvae is very great, and many are serious pests of plants whilst others are parasites of domestic animals. The term *myasis* is used for this last condition. The skin, nasal cavities, and digestive tract are involved in different cases.

Fly larvae are devoid of true legs, and progress by means of blunt protrusions called *pseudopods*. A distinct head is seldom found, this part being much reduced ; the mouth is furnished with well-developed hooks by means of which food is obtained.

The mosquitos, or gnats (family CULICIDAE), while of great importance to the medical man, more especially in tropical countries, concern the British agriculturist to some extent. The family is divided into two groups, the Anophelines and the Culicines, which are distinguished by the differences between the larvae, and also by the palpi in the adult female. The larvae are aquatic, and some species or other will be found breeding in nearly all accumulations of water, however small, in tropical and sub-tropical, and, during the warmer part of the year, in temperate lands also. They are air-breathing, and possess a pair of stigmata on the last segment but one of the abdomen ; in the Anophelines the openings are on the surface, and in the Culicines at the apex of a respiratory tube or *syphon*. The larvae are active, and as a rule feed on diatoms, protozoa, etc. Metamorphosis is complete; the pupa is comma-shaped, and breathes through two trumpet-shaped spiracles. The eggs are

usually numerous, and may be deposited on the surface of the water (or in some cases on damp mud, etc.) either separately, or united into egg-rafts.

The adult males have very bushy antennae, and the palpi are as long as the proboscis, as a rule. In the female

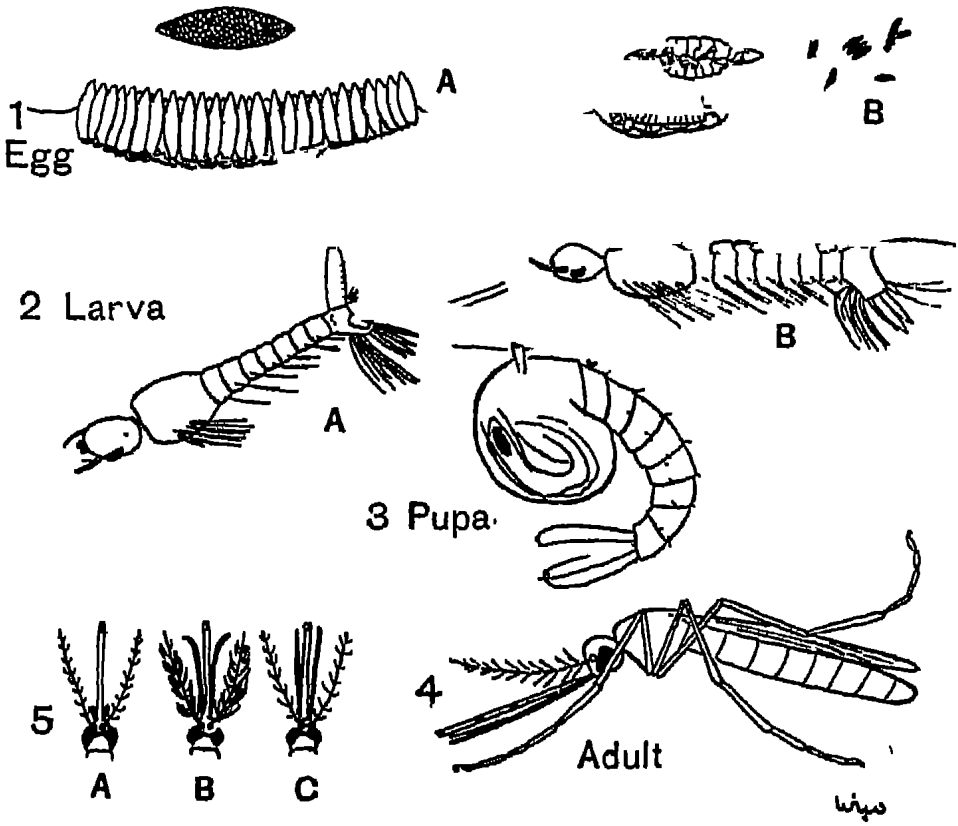

FIG. 10.—Life-history of the Mosquito. (After a wall diagram by Rees Wright.) 1 and 2. A, culicine mosquito; B, anopheline mosquito. 5. A, head of culicine female; B, head of male; C, head of anopheline female.

the antennae are sparsely covered with hair; among the Anophelines the female palpi are as long as the proboscis, whilst among the Culicines they are much shorter. For the most part the Culicines have scales on the body, while these are usually absent in the Anophelines. In both groups the veins of the wings, more noticeably on

the hinder margin, are scaled; this character distinguishes mosquitos from all other flies.

The adult females are blood-suckers for the most part, but will also feed on plant juices. There is some evidence which suggests that plant juices were the original food, and that blood-sucking is a (relatively) recently acquired habit.

The mosquitos have been proved to convey malaria (many species of *Anopheles*), while *Aedes* (*Stegomyia*) *fasciata*, one of the Culicines, is the vector of Yellow Fever.

There are between twenty and thirty species in Great Britain, most of which are uncommon or even rare. The most abundant are *Anopheles maculipennis*, *A. bifurcatus*, and the Culicines *Theobaldia annulata*, *Culex pipiens*, and *Aedes detritus*. This last insect does not concern the agriculturalist particularly, except that in some districts its attacks on man may render work difficult. It breeds in salt marshes, etc., and is a troublesome pest in several South Coast districts. *A. bifurcatus* is also of little direct importance, it is a proven carrier of malaria, and will breed in stagnant or slow-running ditches, etc.; it passes the winter as a larva. The three remaining species winter in the adult stage (4), (6).

In this country *Culex pipiens* does not appear to feed on man, or on mammals, but is said to prefer the blood of birds. It is largely domestic, breeding in almost every conceivable situation, and is usually very abundant in such places as rain-water butts; during the winter it seeks out the cooler places, hen-houses, cellars, and the like, for hibernation.

Anopheles maculipennis and *Theobaldia annulata* both hibernate in the warmer buildings, pig-styes and cow-sheds being the most favoured (9). Both species feed throughout the winter, and some Continental workers have accused them of harming cattle by the amount of

blood they collectively withdraw, but it would seem that they are rarely abundant enough in this country to bring this about. *T. annulata* breeds in water-butts, etc., as does *Culex ;* when there are no animal houses available, it often invades dwellings, and may cause some inconvenience to the inhabitants. *Anopheles maculipennis* is the principal carrier of malaria in Europe. This disease was formerly present in many parts of Britain, but has almost disappeared since the middle of last century. It has been shown by various Continental workers that the decrease of malaria in the countries bordering the North Sea coincided with the introduction of improvement in the housing of farm animals, and it is suggested that the Anophelines were attracted from the cooler dwellings to the warmer animal houses, with abundance of food. When the mosquitos ceased to feed regularly on man, the number of new infections would become very low, or might cease altogether. The evidence available from various parts of Britain supports this view.

The CHIRONOMIDAE (Midges) are delicate flies in which the wings do not bear scales. They are quite abundant in Great Britain. The mouth parts are poorly developed in the adult, except in one group—the CERATOPOGONIDAE,* in which blood-sucking is prevalent. Several species, especially *Culicoides pulicaris*, are frequently very troublesome on summer evenings, especially in damp places, biting persistently, and causing violent irritation. They often swarm in myriads, and their small size enables them to penetrate clothing. In this group some of the larvae are aquatic, while others dwell in decaying vegetable matter, etc.

* Edwards (11) has recently published a monograph of this family, describing 107 British species. The genus *Culicoides* contains about fourteen British species, most of which are said to be blood-suckers.

The family SIMULIDAE contains small and stoutly built flies, with broad wings, short legs, and piercing mandibles. The eggs are deposited in gelatinous masses on stones or plants close to or in water. The larvae are curious and somewhat leech-like in appearance, and attach themselves by their posterior ends to some object in running water; they feed on small vegetable fragments, or diatoms, which are obtained by means of currents set up by two broad, fan-like organs situated upon the head. When mature, a silken cocoon is spun.

The females are often ferocious blood-suckers, and attack man and animals (1). Edwards (2), (3) lists seventeen British species, and states that several of them suck blood, more especially *S. ornatum* and *S. latipes*, and we have ourselves taken *ornatum* and *variegatum* upon working horses in Cardiganshire. On the Continent, in Canada, and in the United States they may occur in enormous numbers and bring about serious conditions among live stock.

The TABANIDAE comprises the Horse-flies, the females of which are well-known blood-suckers. They are stout, bulky, and somewhat flattened flies, with a large head which is convex in front and concave behind. The eyes are very large, and in the male the facets of the upper part of the eyes are larger than those of the lower part. The eyes during life are generally golden-green or purple marked. In front of the head project short, stout, three-jointed antennae, whilst below hangs the fleshy proboscis which encloses the piercing mouth-parts. Some of the species are large insects, and can inflict most formidable bites. About 2,000 species have been described, of which five genera with twenty-one species are British. In colour they are, as a rule, mottled or rich brown, tawny, or grey. The flies are generally met with in summer, in fields and in and about woods, and are most active in warm sunny weather;

their flight is often swift. The males do not suck blood, and are comparatively seldom met with.

The eggs are usually deposited in compact masses on the leaves and stems of plants in watery or swampy places, and the larvae may be called semi-aquatic, although there is evidence that those of certain species live in drier soil. All the larvae are predacious, and devour the larvae of other insects, earthworms, etc. In form they are elongate and tapering, and consist of a head and twelve segments (7). The pupae are similar in form. Abroad, these flies transmit important diseases of stock, such as surra, etc. (5), (8).

At times, and more particularly in the less cultivated

FIG. 11.—*Haematopota pluvialis*. Wing.

districts, these flies may become a great nuisance. Perhaps the most abundant of British species is *Haematopota pluvialis*, the " dun fly " or " cleg." The genus *Haematopota* contains moderate-sized and rather hairy flies of elongate shape, and grey or greyish-black colour, with lighter markings. The wings are peculiarly ornamented by curved hyaline markings on a grey ground (10). This fly alights silently and bites painfully, and on hot days may render working horses difficult to control; one of us has killed 200 on four working horses in a few minutes on a hot June day.

This is a species against which it is difficult to devise control measures, since the larvae appear to live in soil. Comparatively few have so far been found, and recent

prolonged search in North Wales yielded two specimens, and both in soil among root crops. Another less common and much darker species is *H. crassicornis*, whilst several other species are recorded as British.

In the genus *Tabanus* are placed large and moderately hairy flies which are usually brown, black, or grey in colour, with reddish markings and longitudinal rows of grey spots on the abdomen. There are some eight British species, often locally abundant, especially in the

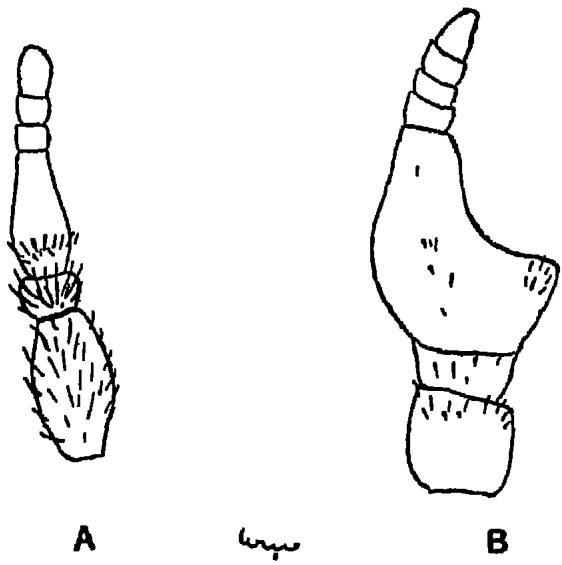

FIG. 12.—Antennae of Tabanidae. A, *Haematopota pluvialis*; B, *Tabanus sudeticus*.

neighbourhood of woods and in clearings. *T. sudeticus* and *T. bovinus* are the largest of all British flies, and can inflict a nasty wound. The flight is powerful, and the deep hum terrifies farm stock. The females of these two species are by no means easy to distinguish. In addition the allied genera *Therioplectes* and *Atylotus* each contain a number of species, some being local or rare, but all capable of causing annoyance when abundant.

Chrysops, likewise, contains several species, all handsomely coloured blackish flies with yellow abdominal

markings and conspicuously banded wings. The eyes are particularly beautiful, being golden or reddish green with purple spots and lines. *C. relicta* is perhaps the most abundant, and widely distributed, and is on the wing from May to mid-August. In all, the flight is silent, and the bite painful.

Abroad, the Tabanids may become a serious menace to stock, and since the majority breed in or near water, efficient drainage and the clearance of watercourses, ditches, etc., as far as possible, has been found of value.

In addition to those described above, several trouble-

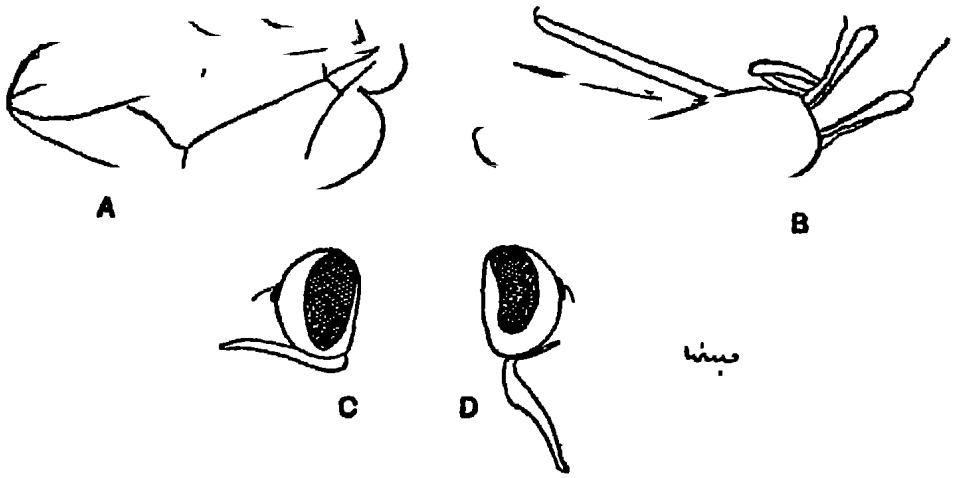

FIG. 13.—*Stomoxys calcitrans*. A, wing; B, proboscis; C, position of proboscis at rest; D, position when feeding.

some biters allied to the common house-fly belong to the family MUSCIDAE, and will be considered here. Species of this family are abundant almost everywhere, whilst many have become widely distributed through human agency. Blood-sucking is not normal to the family, but when present is common to both sexes. The most notorious is *Stomoxys calcitrans*, commonly known as the " stable fly " or " biting house-fly." This species and the next to be mentioned bear a superficial resemblance to the common house-fly, and their attacks are

often attributed to that insect, which is then popularly declared to have taken to biting. In these blood-sucking species the proboscis is usually chitinised, and so becomes rigid, and incapable of retraction. *S. calcitrans* breeds in horse manure, stable refuse, etc., and the period of development varies with the temperature, humidity, etc., from 23–32 days. The ova are laid in batches of 60–70, and a female has been known to produce a total of 600. The fly feeds upon the juices of decaying matter, and animal blood, the latter more especially in hot weather. It is frequently present in large numbers in and about farm buildings, and has been known to bite persistently in the open field.

Another species, *Haematobia stimulans*, is a slightly smaller fly of very similar appearance, habits, time of occurrence, and distribution. *Lyperosia irritans* is a good deal smaller, the female being only some 5 mm. in length. It is closely allied to the two last, and usually attacks cattle. The larvae are found in cowdung, and pupate in the ground beneath it. This insect is of a dull yellowish hue, and has the habit of collecting upon the backs and flanks of cattle or of clustering about the base of the horns. It is most likely to be found upon black cattle, and it is frequently noted that all blood-sucking species evince a preference for black or dark-coloured animals or clothing.

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CHAPTER X

PARASITIC HEXAPODA—DIPTERA (*continued*)

THE blood-sucking members of the MUSCIDAE having been dealt with in the last chapter, it remains to treat of a number of others, among which are some of the most serious of sheep parasites. The first is *Lucilia sericata*,* the " sheep maggot fly " or " greenbottle fly." In this insect the body is from 6–8 mm. in length. The eyes are prominent and purplish in colour, and in the female the space between them occupies one-third of the breadth of the head. The colour is a metallic green. The adult female lays her eggs on the wool of sheep, particularly if it should be dirty or fouled with faeces. The eggs are yellowish-white in colour, and are deposited in batches of 20–50; under favourable conditions they can hatch in less than twenty-four hours. Eggs are also deposited on the dead carcases of rabbits, birds, etc., if available, and this is probably the original and normal habit. It is significant that since the introduction of sheep into Australasia several native species have adopted the habit of ovipositing on sheep.

The larvae (maggots) attack the skin of the sheep, which they penetrate by means of their mouth-hooks, and bore into and feed upon the flesh with results which

* Since the above was written, some doubts would appear to have arisen as to the correct identification of the common " sheep maggot fly " as *Lucilia sericata*. (Richards, O. W. " Notes on the British species of *Lucilia* (Diptera)." *Trans. Ent. Soc. Lond.* Vol. LXXIV. pp. 255–260. December 1926.)

if neglected can only end in the death of the sheep. Growth is rapid, and when full-fed, the larvae leave the carcase to pupate in the earth. The life-cycle occupies 25–30 days in favourable weather (10). These flies are very dependent on weather conditions, and severe attacks usually occur during warm damp weather with dry hot intervals, and are more likely in sheltered situations, in wooded valleys, or amongst high fern, where the sheep tend to remain damp, and in consequence smell more strongly. On the open mountains, in wind-swept regions, and during cool, cloudy, and windy periods, little is heard of this pest. Similarly, during hot dry periods, cases are seldom numerous. Given suitable conditions, infestation may occur at any time from early spring to late autumn; MacDougall says "January, February, March, and December are the only months of the year in which I have no records of the presence of maggots." Sheep, when badly attacked, frequently hide in bushes, fern, etc., which in rough country makes matters worse. A severe outbreak may develop with great rapidity, even after several years of light incidence.

As regards prevention and treatment, little can be done save keeping the sheep clean, pasturing them on the most open and windy land available during hot damp weather; exercising incessant vigilance in examination; and the regular use of preventive powders and dips. Our personal view is that dips are only effective for short periods during bad "fly" weather; and this is especially the case when, as is only too frequent, the dippings are carried out in an irregular, lax, and perfunctory manner. The baths used are frequently inadequate or not cleaned out before use, the fluids employed not kept up to strength, and the sheep are "put through" too rapidly. Oily dips are also frequently used in summer. Lowland flocks can be kept free from serious losses by care and attention, while those on the higher mountains seldom

suffer; the chief difficulty lies with the flocks running on rough hillsides. In any case broken and stained fleeces, slow-healing sores, and loss of condition are usual consequences of ordinary infestation. Carcases or offal of all kinds should be burned. Much work has been done in Australia, South Africa, etc., with regard to the "fly" problem, and methods have been suggested and utilised which are as yet either little known or untried in Britain, where concerted action is difficult to secure. Amongst such measures may be mentioned fly-traps, of which several simple types have recently been described. For instance, Miller (11) has suggested the suspension of a carcase (rabbit, etc.) over a pail or receptable which is partially filled with quicklime. Flies oviposit on the carcase and the resultant larvae in due course fall into the lime. This is visited periodically, and stirred up or renewed. Eight hundred to a thousand blowfly larvae are stated to have been trapped by this means from one rabbit in twelve days.

Miller (12) also very rightly considers that rabbits should be kept down in the vicinity of flocks of sheep, since blowflies are always abundant in and about their warrens, and dead rabbits are an undoubted natural breeding habitat. Smit (17) also has described various forms of traps and their use.

Another "Green-bottle Fly," *L. caesar*, is common in Britain, and is normally a carrion species. The Blue-bottle Fly, *Calliphora erythrocephala*, will also oviposit on sheep at times. This is a much larger insect, reaching from a quarter to half an inch in length, and as much as an inch in wing expanse. The general colour is blue-black on the thorax, and the abdomen is a deep metallic black. The larvae when they attack sheep are largely surface feeders.

The House-fly, *Musca domestica*, is among the most widely distributed of insects. Normally it is about a

quarter of an inch in length. The general colour is grey; the dorsum of the thorax is marked with four narrow and longitudinal black bands, and the sides of the abdomen are more or less buff in the male, and often in the female. The space between the eyes varies from one-fourth to one-fifth of the head-breadth in males (British specimens), while in the females it is about one-third of the head-breadth. The fourth longitudinal vein of the wing is sharply bent near the tip; this is characteristic

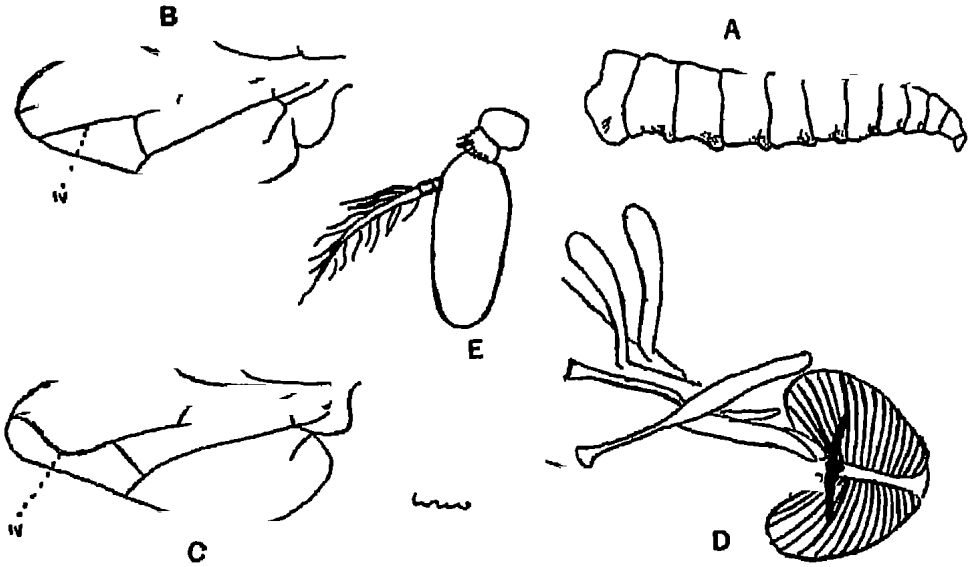

FIG. 14.—Muscidae. A, larva of *Calliphora* sp.; B, wing of *Fannia* sp.; C, wing of *Musca domestica* (note the difference in the ivth longitudinal vein, *iv*); D, *Musca*, mouth-parts; E, *Calliphora* sp., antenna.

of the family MUSCIDAE. The larva is a maggot, and the pupa is of the typical barrel-shaped form.

Musca breeds among decaying organic débris, more particularly in manure. Newstead (15) found that in Liverpool the chief breeding-places were: "(*a*) Stable middens containing fermenting horse-manure, or a mixture of this and cowdung; (*b*) middens containing fermenting hops; and (*c*) ashpits containing fermenting vegetable matter." Among other breeding-places, we

must mention the old-fashioned and most insanitary privies still to be found in most parts of rural Britain. In the case of horse-manure it is most attractive to flies when fresh, and they rarely oviposit on a fermenting mass. To quote Austen (1), "It follows that a manure heap to which no fresh additions are made, but which consists of manure deposited at one time only, can only produce a single crop of house-flies." The period between oviposition and the emergence of the adult fly may be as short as six days, but is usually somewhat longer even under very favourable conditions, while under unfavourable conditions it may be as long as two or three weeks. Before pupating, the larva leaves the spot at which it has been feeding, and may travel several feet. It will be obvious that in such a case as a stable midden, the fresh manure will attract flies to oviposit, while the fermenting mass will keep up a fairly high temperature and shorten the period of development.

Adult flies have a very varied range of food—from foodstuffs such as sugar and milk to decaying excrement; it has been noticed by several workers that human faeces are particularly attractive. Flies have a habit of evacuating the contents of the hind-gut while feeding, and these dejecta may (and do) convey bacteria to foodstuffs. In addition to defaecating on food, they have a habit of regurgitating recently ingested (fluid) food; this is often deposited as a "vomit spot." There is a considerable amount of evidence which incriminates the house-fly as a mechanical agent in the dissemination of various diseases; for fuller information the reader is referred to Graham-Smith (6) and to Hewitt (9). A few instances may be mentioned here. Thus, it is almost certain that *Musca* plays a very important rôle in the dissemination of typhoid and allied fevers. It has been experimentally proved that it can convey the eggs of various parasitic worms. Some observations by Wenyon

and O'Connor in Egypt (quoted by Austen, *op. cit.*) show that under natural conditions they can convey the cysts of *Entamoeba histolytica*, and the eggs of *Taenia saginata*, *Trichuris trichura*, and *Heterophyes heterophyes*, among others. On the farm they may readily convey such organisms as intestinal bacteria to the milk—there are several well-established cases of typhoid epidemics being caused through milk contaminated in this fashion.

In theory, the control of the house-fly is simple, since it consists of abolishing the breeding-places. In practice it is not such an easy thing to bring about. At the same time there is no justification for leaving dumps of garbage scattered about as potential breeding-places. It is foreign to the scope of this book to deal with the question of suitable privy closets, but we may remark that the old-fashioned earth closet should be entirely prohibited upon dairy farms, to say the least. All vegetable refuse and other garbage should be buried, or preferably burnt. Manure should be removed from the neighbourhood of the buildings at once, and if possible scattered ; in a thin layer it soon dries, and flies will be unable to breed in it. There are several methods of storing and treating manure which do not lessen its value for agricultural use. Copeman (see Austen, (1)) has suggested a method of close stacking which has given very successful results. A piece of hard level ground, several feet longer and wider than the intended size of the dump, is selected (if necessary this area should be puddled or concreted). On this each day's manure is used in forming or adding to a compact rectangular dump ; for convenience it should not be more than about five feet high. Each load of manure is pressed down firmly with shovels ; in dry weather it should be moistened slightly. The sides, which should be somewhat sloping, are beaten and smoothed down with the shovel. Baber has described a similar method in which

the dump is surrounded by a gutter-way, which serves to intercept larvae migrating from the manure in search of suitable sites for pupation (2). Such a guttering system will also have the advantage that the valuable liquid manure (too often allowed to run to waste) can be collected and utilised. For other methods of fly-prevention, and for descriptions of privies suitable for use in rural districts, the reader is referred to the work cited above (2).

As an alternative to suitable methods of stacking, the manure may be treated chemically. The U.S.A. Department of Agriculture has investigated this problem, and recommends the use of the three following treatments: "A mixture of ½ lb. calcium cyanamide and ½ lb. acid phosphate to each bushel (1·28 cubic feet). A water extract of hellebore, made by adding ½ lb. of powdered hellebore to 10 gallons of water, using this quantity for each 10 cubic feet of manure. Borax at the rate of 1 lb. to 16 cubic feet. . . ." These substances are added to, and mixed with, the manure as it comes from the stable. Since the method (whichever chemical is used) is somewhat costly, it cannot be recommended save in cases where only small amounts of manure are to be treated (2).

Since flies can travel over considerable distances, it is advisable to screen dairy windows and the like with suitable wire netting.

The family OESTRIDAE is a comparatively small one, but contains a number of important parasites of livestock. The head is large with the eyes widely separated, and the antennae short and placed in pits; the mouth-parts are rudimentary, most of the adults being unable to feed. The body is bulky and somewhat hairy. Coloration usually dull. The larvae are large and stout in build, and are frequently provided with spines. The respiratory openings are at the posterior end of the body. They are endoparasitic in vertebrates, utilising

the stomach or intestines, nasal cavities, mouth, and the subcutaneous tissues, etc., according to their habits, and feeding upon the body-products of their host. Pupation is in the soil. The OESTRIDAE are world-wide in distribution, and there are a number of British species. In nearly all these flies the ovipositor is long and extensile, not adapted for piercing, but for the deposition of ova on the body hairs of the host animal.

The horse Bot-fly, *Gasterophilus intestinalis* (*equi*), is quite well known. It is a brownish-grey and hairy

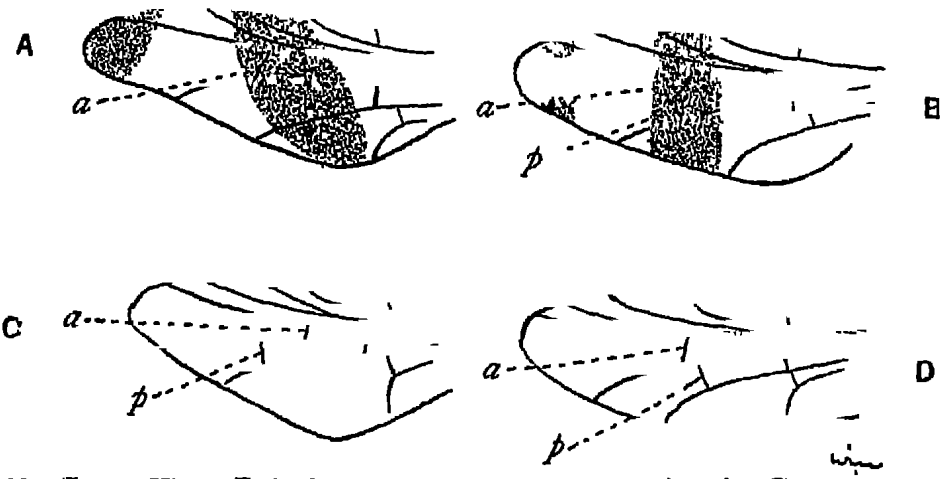

FIG. 115.—Wings of *Gasterophilus* (after Brauer). A, *G. pecorum*; B, *G. intestinalis*; C, *G. haemorrhoidalis*; D, *G. veterinus*. [Note relative positions of anterior (*a*) and posterior (*p*) cross veins.]

insect with black spots on the abdomen. The wings are transparent with dark transverse markings. In the female the abdomen tapers posteriorly. From July to September females may often be seen hovering near horses with the body bent downwards and the ovipositor extended; every now and again the insect darts rapidly forward to affix an egg. The eggs are yellowish in colour and conical in shape, the upper end possesses a distinct operculum whilst the lower end clasps the hair. They are chiefly deposited on the hairs of the forelegs, chest,

shoulders, mane, etc.; the eggs are so firmly attached to the hairs that the empty cases remain long after the larva has hatched. It has been proved that hatching occurs when friction and moisture are supplied, either by the horse biting or nibbling itself, or by another horse, usually after a period of about fourteen days after deposition. On hatching, the young larvae attach themselves to the mucous membrane of the mouth or tongue, and finally reach the stomach. Arrived there, they

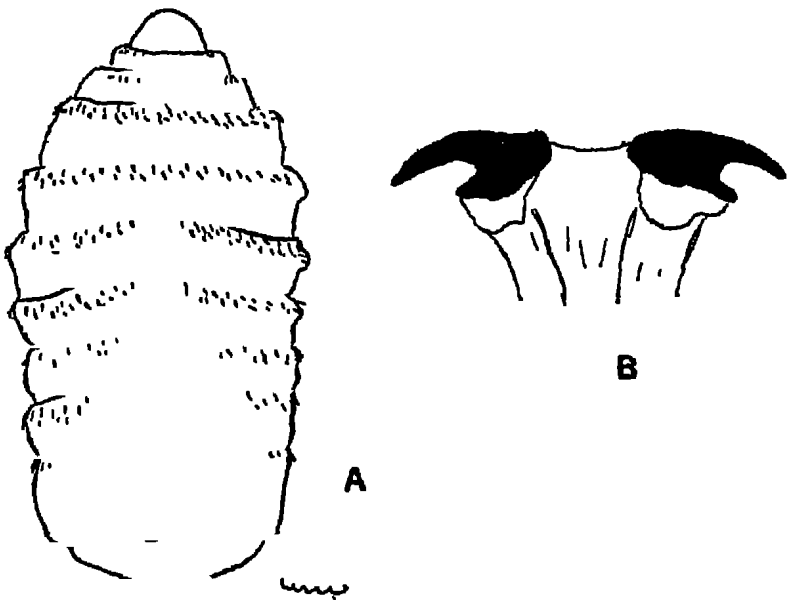

FIG. 16.—*Gasterophilus intestinalis*. A, larva from stomach; B, mouth-hooks of larva.

attach themselves by the mouth-hooks to the mucous coating. They remain in the stomach for about ten months, and are stated to undergo three moults, after which, when fully grown, they loosen their hold and passing out of the body pupate either in the dung or after burrowing a little way into the earth; emergence takes place about six weeks later (7), (8).

The larvae are known as "bots," and the injury they may do depends largely on their abundance and

position; if present in large numbers they may cause serious irritation or even obstruct the passage of food. On the other hand, although the majority of grazing horses must harbour a number, serious symptoms are but seldom met with. Treatment is best left to a veterinarian. Prevention is more hopeful, since regular grooming will remove or bring about the hatching of the egg and destroy the young larvae. It has been stated that this can also be accomplished by periodical light brushing of the coat with a cloth dipped in dilute carbolic (1 in 30), etc.*

There appears to be room for further investigation as to the life-history and control of this pest, and this remark also applies to the three other species which have been reported from the British Isles, *G. pecorum*, *G. haemorrhoidalis*, and *G. nasalis*. Records of all these are very scant, and much remains to be done before the distribution, etc., of these species is cleared up.

In *G. pecorum* the life-cycle is stated to be similar to that of *intestinalis*; but in *haemorrhoidalis* and *nasalis* (*veterinus*) the eggs are placed below the chin, about the lips, etc. A good deal has been done in other countries regarding the life-histories and bionomics of these flies (3), (5), (7).

The nomenclature and systematic position of these insects is also by no means satisfactory. Most writers retain them in the OESTRIDAE, whilst others would remove them to a subdivision of an entirely different family, the ANTHOMYIDAE. Furthermore, some writers place them in the genus *Oestrus* (see the next species described below), whilst others retain the more usual *Gasterophilus*, and even this is often spelt *Gastrophilus*. These

* BISHOPP, F. C., and DOVE, W. E., *U.S. Dept. Agric. Farmer's Bulletin* 1503, give useful details regarding life-history, treatment, and prevention; they state that a 2-per-cent. solution of any good coal-tar creosote dip, applied by means of a rag at intervals of six days, will destroy the eggs.

remarks are made in order to show that much still remains to be done in connection with parasites of British live-stock.

Oestrus ovis, the "sheep nostril" or "nasal" fly, is about half an inch in length; yellowish-grey in colour, with a curious spotted or mottled abdomen. The fly is slightly hairy, and the wings are transparent. The female usually deposits small creamy-white larvae, which are about 1·5 mm. in length, within the nostril of the sheep. It is stated that towards the autumn eggs are so placed. The flight of the fly is very rapid, and is accompanied by a peculiar buzzing noise, which alarms the sheep, causing them to run together with their heads held low. They will also rush about, sneezing and applying the nostrils to the ground, in an endeavour to prevent the fly from ovipositing. The larvae are provided with two hooklets, by means of which they adhere, and subsequently work their way up the nasal passages, until they reach the frontal sinuses or spaces of the skull. Here they settle down for about ten months, feeding upon mucus and products of the inflammatory condition they set up. They become darker in colour and attain a length of about 18 mm., becoming adult in June or July of the year following infestation. They then release their hold, are sneezed out by the sheep, and pupate in the earth.

During spring and early summer there is a discharge from the nostrils of infested sheep, varying, however, with the number of larvae present, which ranges from 2–20 or even more. When infestation is severe the sheep are much weakened, and losses may occur. At times the symptoms may rather resemble those described under "gid," but the occurrence in all ages, the mucous discharge, and other points, should readily prevent confusion between the two. Although widely distributed, this parasite is not normally present in large numbers,

being subject (as also are many other parasitic species) to periodic fluctuations, periods of alarming abundance being followed by others of comparative scarcity.

Remedies seem to be of little value, and prevention as usual is the chief hope. The following are among the methods which have been suggested: (*a*) Smearing the nostrils with Stockholm tar, fish oil, etc., to render them unpleasant to the fly; (*b*) provision of dark shelters for the sheep upon infested land, or of dust-heaps or furrows in which the sheep may shelter the nostrils; (*c*) removal, as far as possible, from known infested areas (which may be comparatively localised) during the "fly" period; (*d*) the segregation of known infested sheep about the time of larval discharge with the object of the destruction of the larvae to prevent further infestation of the pastures.

The most harmful of all the stock pests of this type, however, are the larvae of the "Warble-flies," *Hypoderma lineata* and *H. bovis*. Both these flies are widely distributed in Great Britain, and are a source of great annoyance and loss each year (20). Both species are large, hairy flies, with a superficial resemblance to small humble-bees, and are rather alike in appearance, the general coloration being black, banded with yellowish or orange hairs. *H. bovis* is the larger, and has whitish hairs over the front of the body and lemon-yellow hairs at the tail, whilst in *H. lineata* the front region is largely bare and there is a bright orange tuft posteriorly (13). Both species may occur about equally in the same district, or either may predominate. *H. lineata* is on the wing earlier than *bovis*, and is stated to be less affected by, and will oviposit at, considerably lower temperatures (4).

Injury to stock arise from (*a*) the annoyance to cattle, and "gadding," caused during oviposition; (*b*) the irritation and injury produced by the activities of the larvae within the body of their host. (*c*) There is also the loss

of meat due to spoilt flesh when infested cattle are slaughtered, and the very considerable damage done to hides, which is stated at £400,000 to £500,000 per annum in the worst years (14).

Eggs are laid by the females on the hairs of the hind leg, *bovis* placing them singly, whilst *lineata* attaches a number to one hair, and it is believed that *bovis* is more often the cause of "gadding" than is *lineata*. Older cattle are less severely attacked than are young ones. In from three to six days small grubs emerge from the eggs, crawl down the hairs, and bore their way into the skin, using for this purpose a pair of very strong mouth-hooks. These larvae measure about 3 mm. in length. For about seven months thereafter, there are no external signs of these grubs, which live and wander in the tissues beneath the skin. They undergo a moult during this period and by winter have attained a length of 15–17 mm. They now migrate to the dorsal region of the host, and arriving there, rapidly cut a breathing-hole through the hide; they become surrounded by a wall or cyst, undergo several moults, and grow rapidly. The routes taken after entering the skin as larvae and before reaching the back appear to vary, and are not yet fully known; but considerable numbers reach the tissues between the mucous membrane and the muscular wall of the gullet, prior to migrating to the dorsal region.

As in others of the same family, the respiratory orifices are reduced to two, which are situated posteriorly, the warble larvae applying these to the orifice that they have made, in order to obtain air. As growth proceeds the grubs become thicker, more spiny, and darker in colour, and a swelling or "warble" forms, within which the larva feeds upon the products of the inflammatory condition set up. Finally, the grub works its way out through the enlarged orifice, falls to the ground, and seeks protection under any loose material available. The

skin shrinks and hardens, and within this the fly develops, to emerge from 30–60 days later.

This interesting life-history has been revealed as the result of prolonged investigations by numerous workers, prominent among whom have been Professor Carpenter in Ireland; Dr. Hadwen in British Columbia; and Dr. Glaser on the Continent.

Larvae of both species will now and again occur on horses, and whilst the resultant swelling is generally smaller than in cattle, it may cause considerable trouble. It is probable, however, that the life-cycle is very seldom completed in this unusual host.

As regards control, many methods have been tried. Prevention of oviposition is the ideal, but has not given useful results so far. Squeezing out the grubs has been advocated and tried, especially in Denmark, and by Carpenter and his colleagues, who cleared Clare Island by this means between 1915 and 1920. In the case of wider areas, however, this method has obvious disadvantages, and dressings have latterly held chief place.

The Ministry of Agriculture have recommended a wash of tobacco-powder and lime in water, and good results are reported from its use. In the United States much work has been carried out, using ointments and fine powders which are pressed into the orifices on the warble. Amongst the most effective may be mentioned derris, used as a wash or as an ointment; iodoform or pyrethrum, as ointments; benzol and carbon tetrachloride injected; also fine tobacco powder and nicotine dust applied dry (4). The British Ministry of Agriculture also recommend derris, and nicotine sulphate and lime (14). The senior writer has recently carried out experiments in North Wales using iodoform and derris ointments with good results, iodoform proving superior in healing properties (18), (19). In these cases four applications are needed at intervals of a month or five weeks

in order to destroy the warbles in series as they appear, since if both *lineata* and *bovis* exist in a herd, larvae will continue to do so over a prolonged period. Whatever remedy is utilised must be applied with regularity and thoroughness over as wide an area as possible.

Yet another family remains to be considered, the HIPPOBOSCIDAE, which are flattened insects of leathery consistency, markedly adapted to ectoparasitic life. The best known is *Melophagus ovinus*, the very abundant "ked" or "sheep-tick" (as it is often misnamed). In this species wings are represented by vestiges in the form of a pair of disc-like cutaneous structures borne on the dorso-lateral surface of the thorax, and the insect passes its whole life-cycle on the sheep. *M. ovinus* measures from 8–10 mm. in length, and is brown in colour, although pale in newly hatched individuals. As in all this group the fertilised eggs are retained and develop throughout the embryonic and most of the larval stages within the body of the female, who finally gives birth to a larva which pupates within a few hours. As a consequence the number of young produced by each female insect is greatly reduced, and is said to average 10–12. The pupal period is stated to last for 19–24 days, maturity being attained about fourteen days later, the entire life-cycle occupying somewhat over a month. The Ked is a blood-sucker and causes great irritation, so that any undue increase in numbers will soon be noted in loss of condition and in dirty ragged fleeces.

As has already been mentioned, a part of the life-cycle of a Protozoan blood-parasite of the sheep is passed in the ked (from which it was, in fact, first described), but this organism, as far as is known, is harmless. Keds are readily controlled by the use of ordinary dips; two dippings 28 days apart are usually sufficient.

Hippobosca equina, the so-called "Forest Fly," is so named from its principal location, the New Forest. It also

occurs in some of the valleys of South Carnarvonshire and North Merionethshire, and a few other districts; in any case it is very localised, and in consequence little known. It is a blood-sucker, and attacks horses and cattle, and on the latter may be seen clustering below the genitalia or on the udder, etc. The bite does not seem to be resented, but animals not inured to the presence of these flies are driven frantic by the attentions of a single individual. This is apparently due to the fact that their strongly toothed claws enable them to climb about actively, pulling the hairs and causing an intense tickling. This was a much more serious matter in the days when horse transport predominated, although awkward cases occur even now. Both sexes are winged and will fly freely.

From recent work (16) carried out in North Wales, it would appear that the pregnant female flies leave the host and deposit their larvae amongst the decaying humus found about the stems of bracken. The larva is then globular in form, and creamy-white in colour, with a black patch and two conical posterior projections. Pupation follows very quickly, the integuments hardening and becoming almost black. The fly may be observed from May to August.

Another form, *Lipoptena cervi*, is found upon deer of various kinds. An interesting point in connection with this species is that at hatching both sexes are winged, but the wings of the female break off close to the back after she has settled upon the host.

The genus *Ornithomyia* is represented in Britain by several species which are bird parasites. *O. avicularia* is common, and occurs upon a considerable range of hosts.

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CHAPTER XI

PARASITIC HEXAPODA—SIPHONAPTERA (APHANIPTERA) (FLEAS)

THE Fleas (order SIPHONAPTERA or APHANIPTERA) are a very interesting and peculiar group of insects, and in structure show many adaptations and specialisations to their mode of life. Their origin and their relationship to other insect groups is obscure, and there has been much discussion, and difference of opinion, as to their place in classification. Their life-histories disclose well-marked metamorphoses which "possess certain features in common with the Diptera Nematocera" (3).

Fleas are blood-sucking ectoparasites of mammals and birds. They are small in size, and generally light to dark brown in colour. The body is peculiar in being laterally compressed (flattened from side to side) instead of in the dorso-ventral manner so usual among other parasitic forms. The head is small, and eyes may be present or absent. The antennae are short, and lie in grooves at the side of the head; the mouth parts are adapted for piercing and sucking. The head is applied to the thorax without the usual "neck" so generally found in insects, and the thoracic segments are similarly attached to the abdomen, giving the whole insect a remarkable compactness and strength. A considerable number of spines and bristles are present, but no trace of wings. The legs are strong, particularly the coxae, and are utilised for making considerable leaps, which is

the usual method of progression when apart from the host. Fleas not infrequently leave the host, from which the life-history of the typical flea is entirely dissociated.

The eggs are rounded, and white or creamy in colour. They are in no way attached, but either fall from the host on which they are laid, and normally develop in its nest or sleeping-place, or are deposited in cracks or crevices of floors, barns, etc., or in litter. Hatching takes from 3–10 days: the larva possesses a well-developed head, and an elongate body of thirteen segments; it feeds on organic matter, and finally pupates within a cocoon. There is an interesting feature connected with hatching: "The adults remain quiescent for a variable period before emerging from the cocoon, and they often issue in large numbers in response to slight mechanical stimuli. The vibrations set up by persons walking about a disused room, for example, have been explained as being the cause of the emergence of an abundance of fleas within a short time. When newly emerged, the adults can remain for a considerable period without food, but they usually take the first opportunity of reaching their particular host" (3).

Although no less that forty-six species of fleas are listed as British (5), (6), yet few of them are of importance to the agriculturalist, who may have to deal, however, with such cases as a heavily infested cottage, or an out-building where dogs have been housed.

The chief species are (*a*) *Pulex irritans*, the human flea, but also occurring on the badger, fox, and some other mammals; (*b*) *Ctenocephalus canis*, the dog flea; (*c*) *C. felis*, that of the cat; (*d*) *Spilopsyllus cuniculi*, of the rabbit; and (*e*) *Ceratophyllus gallinae*, the hen flea. This last is the only one occurring on fowls in this country; it will also breed in the nests of other birds, such as sparrow, starling, and blackbird. It is frequently abundant in dark, dirty fowl-houses and nests,

and may then be a cause of irritation and loss of blood, with resultant loss of condition. Eggs are deposited in dust and dirt, on floors and in crevices, etc. (as stated above), chiefly in warm weather, although breeding may continue throughout the year, especially in the milder areas.

Fleas are very fond of warmth, and should the host die or be killed, all rapidly leave the body, and may then infest unusual hosts. Blood-sucking, which is followed by severe irritation and swelling in some cases, is accompanied by a habit which in appropriate circumstances results in certain fleas becoming a menace to the entire population. Whilst feeding, the contents of the gut, which may contain disease germs, are voided at intervals, and should these be introduced into the blood system through the puncture, by scratching, etc., infection is likely to follow. It is thus that rat-fleas may play so important a part, since plague is a disease of rats, and is communicated to man by the fleas.

Bacot and Martin's classical investigations (1) on the transmission of plague by fleas have shown that infection may be brought about apart from the fouling of the bite by bacteria-laden faeces. They found that when fleas were fed on infected rats, the bacteria ingested with the blood developed in the proventriculus and mid-gut generally, until the alimentary canal was blocked. At this stage, any blood ingested by the flea was regurgitated as soon as the insect stopped sucking, and carried back with it numerous plague germs. Since the fleas could not retain their food, they became very ravenous, and more inclined to feed off unusual hosts than is normally the case.

Ceratophyllus fasciatus, the most common rat-flea in this country, is stated to bite man, and is capable of carrying plague, as is also the human flea, and various others. No less than twenty-six species of flea are

recorded from the brown and black rats and the house mouse (7). Although bubonic plague is now normally absent from Great Britain, yet within recent years isolated outbreaks have occurred, due to infected rats, usually imported by shipping. With the great numbers of rats usually present on farms, etc., it behoves all to endeavour to destroy them, quite apart from the enormous damage done by them to buildings, grain, poultry, etc. (2).

In addition to plague, rats can assist in the transmission of other diseases, as well as parasitic tape- and round-worms. It must be remembered that although fleas have certain hosts on which they normally occur, they will attack almost any warm-blooded host should food be scarce (4).

Control. — Cleanly and light airy buildings are essential, with floorings that do not provide cracks or crevices to accumulate dirt or refuse. Infested rooms, after being thoroughly swept out, can be treated by scattering naphthaline on the floor. This stupefies the fleas, which can be swept up after an interval of twenty-four hours. A thorough spraying of paraffin emulsion is also said to be of value. Fumigations with sulphur, hydrocyanic gas, etc., are excellent when practicable. For personal use, eucalyptus oil, iodoform, and oil of pennyroyal are all recommended. Dogs can be cleansed by washing with carbolic soap, or with 3 per cent. creolin, and cats by means of powdered naphthaline, pyrethrum, or derris. Rats and mice should be destroyed and excluded.

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CHAPTER XII

COLLECTION AND PRESERVATION OF PARASITES

It will be convenient to consider this subject in two divisions, the collection of permanent parasites—including insects such as lice, fleas, etc.—and the collection of temporary parasites. Much of the apparatus required will be common to both groups.

(A). For the collection of permanent parasites it will be necessary to have a few dissecting instruments. These will usually comprise two or three strong knives—of sizes suited to the animals to be opened—two or three scalpels (medium and small), at least two pairs of forceps (fine pointed, straight and curved), at least two pairs of scissors (similar to the forceps), and, with advantage, a pair of common stout scissors, and, if much examination of intestinal contents is to be carried out, either an enterotome (a special kind of scissors made for the purpose) or a medium-sized scissors of which one blade is blunt-ended, while the other is about one-quarter of an inch shorter; in opening the gut the blunted point is inserted into the cavity. A few camel-hair brushes of various sizes are very useful (indeed, almost essential) for picking up the smaller worms and the parasitic insects.

Specimens are preserved in a suitable reagent in corked glass tubes. It is of great advantage, where a collection is being formed, to have all the tubes of the same bore, but of varying length, since racks can easily be made to take any number of them by drilling

holes, about an inch deep, in thick pieces of wood. A very useful series of tubes would be 1¼ inches in width by 2, 3¼, and 6 inches in length; the medium-length tubes will conveniently hold two microscope slides back to back for staining, etc. For very minute specimens, a few tubes either ¼ inch or ½ inch in width by about 1½ inches in length are useful; with these the mouth should be plugged with cotton wool after the specimen has been inserted and the tube filled with the preservative. Several of these small tubes (containing specimens of the same species or genus) can be placed together in one large one.

Labels should be written in pencil, or in fixed Indian ink, on either unsized paper or, preferably, on parchment paper. On the label should be written the name of the species (if known) with the date and locality, and the collector's name or initials. Full data should be taken at the time of collection, in a rough notebook, and afterwards transcribed into a more permanent book, sections of which (or, preferably, separate books) should be alloted to each group of parasites.

Protozoa.—These may be present in the alimentary canal, in the blood, or in other tissues.

Protozoa in the alimentary canal will generally be found in the faeces, as will also the cysts of forms inhabiting the gut or liver tissues. For preservation, a small quantity of the faeces is mixed with two or three times its volume of 5 per cent. formalin (commercial formalin 1 part, water 7 parts), and kept in a tube. The fresh material is examined in thin films. A very small quantity of the faeces is placed on a microscope slide, and rubbed up in a drop of water or 0·7 per cent. salt solution until translucent; it is then covered with a No. 1 cover-slip and examined under a high power of the microscope.

Blood protozoa may be examined alive or in stained preparations. In the first instance a drop of blood is

placed on a clean slide, and a No. 1 cover-slip dropped on to it. To make a film for staining, place a *small* drop of blood near the end of a slide; take a second slide (preferably with the corners broken off so that one end is narrower than the first slide), place the end just touching the drop, and move *fairly* rapidly towards the further end of the slide. Allow the film to dry without heat. Films are usually stained with Leishman's stain. On the dried film pour about 10–20 drops of a methyl-alcohol solution of the stain, seeing that all the film is covered; after 30 seconds to 1 minute add twice as much distilled or rain water as stain, mix with a glass rod, and allow the mixture at least 5 minutes in which to act. Wash off with water, and leave to dry. Mount in Euparal with a No. 1 cover-slip.

Protozoa in tissues must be studied in thin sections, the preparation of which is foreign to this book. For information on this matter, the reader is referred to Bolles-Lee (1) or Langeron (3). Suspected material is best preserved in the following manner: Cut the tissues into slices not more than 5 mm. thick, if possible, and throw into a vessel containing :—

(*a*) Picric acid (saturated aqueous sol.) .. 30 parts
Formol (commercial formalin) .. .. 10 parts
Glacial acetic acid .. .. .. 2 parts

or (*b*) Alcohol, 96 per cent. .. .. .. 1 part
Saturated aqueous sol. mercuric chloride 2 parts

The first mixture is the better.

After about half an hour, or somewhat longer if the pieces are large, remove from the reagent. Material treated with (*a*) " Bouin's fluid " should be stored in 70 per cent. alcohol. Material treated with (*b*) " Schaudinn's fluid " should also be transferred to 70 per cent.

To this latter tincture of iodine is added drop by drop until a faint straw colour is reached and does not disappear on shaking; the tissue is then transferred to clean 70 per cent. alcohol for storage.

Full information on the methods of study, etc., will be found in Wenyon (4).

Parasitic Worms.—Faeces containing eggs are treated with formalin as described above. Permanent mounts are best made by placing a small quantity of the preserved faeces on a slide and mounting in glycerine jelly.

The adult worms can be obtained in good condition only at post-mortem examinations of infested animals. The intestines are slit open, preferably with the enterotome or the blunt-pointed scissors, and the contents collected into a bucket or other suitable receptacle. The walls of the gut are gently washed with a stream of water, and any worms attached removed as gently as possible, with a mounted needle or a brush rather than with the forceps. The contents can be examined for worms in several ways, which can also be used in the examination of faeces for expelled worms after the examination of anthelminthics. The material is shaken up with water, and the supernatant fluid poured off, this being repeated several times. Alternately the material may be shaken up with many times its bulk of water (with faeces it may be necessary to stir the mass until it is thoroughly broken up); the fluid, with the suspended material, is then poured on to a gently sloping slate slab or sheet of metal several feet long, and washed down it with a gentle current of water. In either case the worms—except large forms such as *Ascaris*, which may be secured with forceps—are picked up with needle or brush, and transferred to normal (0·7–0·9 per cent.) salt solution. This solution, with the worms in it, is gently shaken to wash away débris; it may be necessary to do this several times, using fresh liquid each time.

Worms, such as the Liver Fluke, which live in organs other than the alimentary canal, are secured by carefully opening the passages in which they lie. They also are to be washed in salt solution.

Worm cysts are to be removed as gently as possible from the tissues in which they occur, dissecting them out if necessary.

Trematodes may be killed by throwing them into a saturated solution of mercuric chloride or into 10 per cent. formalin. It is, however, preferable to lay them out on a sheet of glass, covered with a sheet of lighter glass (such as a cleaned photographic plate of appropriate size), and to run the solution between the two glasses. Warm Schaudinn's fluid, with the addition of 5 per cent. of glacial acetic acid, is also used. After mercuric chloride or Schaudinn the worms must be washed in alcohol with iodine as described above before being stored in 70 per cent. alcohol.

Larval trematodes are obtained by dissection of the invertebrate host. The arrangement of the "flame-cells" of the cercariae can only be studied in living specimens. Permanent mounts may readily be made by fixing with Bouin's fluid and staining with carmine or with haematoxylin. The larvae to be fixed are placed in water on a slide, and covered with a No. 1 cover-slip. Excess of water is drawn off with a strip of blotting paper; the fixative is placed (with a capillary pipette) at the opposite edge of the slip, under which it runs to replace the water removed. After an interval of about ten minutes excess of fixative is added, and the cover is gently raised, when it will be found that the majority of the organisms are attached to it or to the slide. Without being detached from the glass, they are treated with alcohols of decreasing strength (beginning at 70 per cent.), and finally with water. After washing, the worms are transferred to the staining solution. The stains which

have given the best results in the hands of the writers are (*a*) acetic-acid alum carmine, and (*b*) Haidenhain's iron-haematoxylin, for particulars of which the reader is referred to Lee (1) or Langeron (3). After staining, the material is treated with alcohols of increasing strength, and mounted in Euparal from 95 per cent.

Cestodes may be treated in the same way as trematodes ; care should be taken to secure the head or scolex, which is essential for identification.

Nematode worms are best killed by being thrown into hot 70 per cent. alcohol, in which they die extended. They are preserved in 70 per cent. alcohol to which about 5 per cent. of glycerine has been added.

Trematodes and cestodes (the scolex and neck, and segments from different parts of the strobila) are best studied in permanent mounts. The specimens are preferably stained with alum-carmine, and mounted in Euparal, or in xylol-balsam, after clearing with clove oil. Nematodes can be studied after clearing with carbolic acid, to which they are transferred from 70 per cent. alcohol ; after examination they are replaced in the alcohol. Permanent mounts can be made by clearing in pure carbolic acid, and mounting in Euparal,* but better results have been obtained by the use of a medium devised for this purpose by the junior author. To prepare this, take equal weights of flowers of camphor and of purest phenol ; rub together in a mortar, and to the resulting oily liquid add twice its volume of a thin solution of gum sandarac in isobutylic alcohol. Specimens may be mounted in this direct from 70 per cent. alcohol.

Arthropods such as ticks and mites are best killed in hot water or in alcohol ; this last can be employed for fleas and lice also. Mites, lice, and fleas may be mounted, after soaking in strong alcohol, in Euparal, or in the writers' medium. Young ticks may be treated in the same

* This method gives good results with Trematodes also.

fashion, but older specimens may have to be treated with 10 per cent. caustic potash before mounting. In this reagent they are left for several days, after which they are transferred to 10 per cent. acetic acid, washed in water, and treated with strong alcohol before being mounted. If necessary, any of these organisms can be stained with carbol-fuschin before mounting.

Ticks are removed from the host with forceps or with the fingers; care should be taken not to damage the mouth-parts by too rough removal. Mites, fleas, and lice are best picked up with a brush damped with alcohol.

While the majority of semi-parasitic insects are treated as described in Section B of this chapter, the larvae, and such parts as the male genitalia, are often preserved as microscope preparations. Genitalia, or entire small larvae, can be treated with potash, stained with carbol-fuschin, and mounted in Euparal, or they may be mounted direct into the phenol-camphor medium after soaking for some hours in 70 per cent. alcohol. The mouth-hooks, etc., of the larger larvae can be treated in the same manner. Entire larvae are best killed in warm 70 per cent. alcohol, and preserved in the alcohol-glycerine mixture recommended for nematodes.

(B). For the collection of temporary parasites (which from the point of view of this book are the Diptera) are required, in addition to specimen tubes, an entomologist's net, chloroform, a supply of entomologist's pins (black, size 7 for the larger insects, and size 20 for the smaller ones, such as mosquitos), a sheet of prepared cork, and some cork-lined store-boxes. The curved forceps mentioned in the preceding section may be used in mounting, but for the larger insects it is advisable to have a proper entomologist's forceps. In addition, a supply of thin cardboard (such as is used for visiting cards) is useful for labelling.

The insects, caught in the net, are transferred to an

empty specimen tube; this is carefully inserted into the net with its mouth open, and placed over the insect, the mouth is then covered with the thumb, and after withdrawal from the net the tube is plugged with cotton-wool in place of the cork. The insects are killed with chloroform; a few drops are poured on to the cotton-wool plug, which is then pushed down the tube, and the cork is inserted. As soon after death as possible the insects should be pinned. If they cannot be pinned, they should be packed in loose tissue paper rather than in cotton wool.

To Pin Insects.—Place the insect on a corked sheet, pick up with the forceps a pin of suitable size, and thrust it through the thorax of the specimen from below, inserting it between the legs, until about two-thirds of the length of the pin projects below. Set the wings at right angles to the body, using the fine forceps, and spread out the legs with a mounted needle. Care should be taken not to remove any bristles from the body, as these are often of great importance for correct identification. With the smaller insects especially, half the specimens should be pinned from one side; in this case the pin is not thrust through the body. After pinning, the head of the pin is cut off with a stout scissors, and the insect is placed in the store-box.

For collections, insects are often mounted in a slightly more elaborate fashion than has just been described; for particulars of this, and further information as to methods of collection, etc., the reader is referred to the British Museum (Natural History) "Instructions for Collectors," which can be obtained either as one bound volume or in separate parts, of which Nos. 4, 5, 6, and 7 deal with insects, while No. 12 deals with the collection of parasitic worms.

Reference has previously been made to the use of alcohol as a preservative. The "methylated spirits"

sold in shops is of no use whatever for this purpose, as it will not mix with water, certain substances having been added in order to render it unfit for drinking. What is known as " Industrial methylated spirits " is entirely satisfactory, but can only be obtained in large quantities under licence. " Proof spirit," which may be obtained from a chemist, is satisfactory but somewhat expensive. At a pinch specimens can be preserved temporarily in spirits (whisky, brandy, or rum). It may be remarked that alcohol which does not light when a flame is applied without previous heating, is too weak for the final preservation of material. The reader who contemplates doing much collecting is strongly advised to get in touch with the nearest zoological or pathological laboratory.

In addition to the collecting equipment already mentioned, a certain amount of apparatus is required for the more detailed study of the material obtained. For rough examination, a good botanical (" triplet ") lens, or an aplanatic lens of power ×6 or ×10 is sufficient. No reference need be made here to microscopes and their accessories such as are to be found in every fully equipped laboratory, but it may be stated that efficient microscopes of the " Student " type, and binocular and other dissecting types, can all be obtained at very reasonable prices.

The principal literature of the subject has already been referred to in the bibliographies attached to the various chapters. It may be convenient, however, to list together the principal journals containing parasitological articles. *Parasitology*, edited by Prof. G. H. F. Nuttall, and published by the Cambridge University Press, and the *Annals of Tropical Medicine and Parasitology*, edited by the Staff of the Liverpool School of Tropical Medicine, contain papers dealing with the entire range of human and animal parasites. The *Journal of Helminthology*, edited by Prof. R. T. Leiper and published by the London School of Hygiene and

Tropical Medicine, is devoted to helminths. The *Bulletin of Entomological Research*, edited by Dr. G. A. K. Marshall and published by the Imperial Bureau of Entomology, deals with insects. The Bureau also issues the *Review of Applied Entomology*, Series B of which contains summaries of practically all papers dealing with parasitic arthropods. These journals (apart from the *Review*, which appears monthly) are issued quarterly. Parasitological articles occasionally appear in other technical journals devoted to Zoology, Medicine, and Veterinary Medicine. More popular articles appear from time to time in the *Journal of the Ministry of Agriculture*, which is issued monthly.

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APPENDIX

Zoological Classification

The unit in Zoology is the *species*. All animals grouped together in a species are, with the exception of differences due to sex or age, or to slight individual variations, morphologically (structurally) identical. Under suitable conditions members of a species will breed and produce fertile offspring. Species which closely resemble each other are grouped together into a *genus*. We may take the house-fly and its congeners as an example. The common house-fly in this country is known as *Musca domestica*. In India there is a very similar fly known as *Musca enteniata*. These two species are grouped together with some others into the genus *Musca*. This genus is found to be very similar to certain other genera, *e.g. Glossina* (the tsetse flies), and with them is grouped into a *family*, the Muscidae. The Muscidae agree with other families in certain characters, and with them are classed together as the *order* Diptera. The Diptera again are grouped with other orders to form the *class* Hexapoda; and, finally, the Hexapoda, with other classes similar to it, form the *phylum* Arthropoda. For convenience of classification, these groups are often subdivided into sub-orders, sub-families, etc. The individuals of a species, especially of one that is large and widespread, may often show small constant differences, which are known as *varieties* or *sub-species*; such sub-species are often due to differences of environment.

Zoological Nomenclature

In order to secure a uniformity of nomenclature, the International Congress of Zoology in 1898 set up a Commission, as a permanent body, to formulate a Code of Rules of

Zoological Nomenclature (usually known as the International Code). The latest (1913) Code may be found in Wenyon (see p. 18, *supra*), while an excellent summary is given in the War Office "Memoranda on Medical Diseases in Tropical and Sub-Tropical Areas," pp. 269–272 (1924). We may with advantage summarise those articles of the Code which concern the student.

Art. 2. "The scientific designation of animals is uninomial for sub-genera and all higher groups, binomial for species, and trinomial for sub-species." As an example we may take the human louse. The genus is *Pediculus*, the species (binomial) *P. humanus*, and the sub-species found on the head *P. humanus capitis*.

Art. 3. "The scientific names of animals must be either Latin or Latinised. . . ."

Art. 8. "A generic name must consist of a single word, simple or compound, written with a capital initial letter. . . ."

Art. 13. "While specific substantive names derived from names of persons may be written with an initial capital letter, all other specific names are to be written with a small initial letter. . . ." It is recommended, and is now customary, to distinguish the scientific names of animals by printing them in a different type from that used for the rest of the text; generic and specific names are usually printed in italics (or underlined in manuscript), while the names of the higher groups are often printed in small capitals (or double underlined).

Art. 25. "The valid name of a species or genus can be only that name under which it was first designated . . ." under certain given conditions. This is the all-important Law of Priority. At the present time its application is causing some slight confusion, since it is found that many hitherto-accepted generic and specific names are not valid. (The Commission has the power to suspend the Rules in any case where they consider, after having received the opinions of zoologists, that a change would cause more confusion than is justifiable.) If a generic name be used a second time, even in a different Phylum, it is a *homonym*, and not valid, *e.g.* Owen in 1835 established a genus *Trichina* for certain nematode worms, but since Meigen had used this name for a genus of

insects some years previously, Owen's name is not valid, and another name has to be found (the genus is now known as *Trichinella*). If the same specific name is given to two species within a genus, the name later in date is a *homonym*, and not valid; the name cannot be used even if the species is subsequently placed in another genus. When two or more names are given to a genus or species, the earliest valid name is the correct one—all others are *synonyms*.* A synonym may be used for a new genus or species. When a name is given to an animal without sufficient indication to enable us to identify the animal, it is a *nomen nudum*, and of no status. It is recommended that when a new species is described, a single individual should be made the type. (Such individuals are known as type specimens, and are among the treasures of the collections in which they occur.) When a new genus is described, a type species should be indicated.

The enforcement of the Code may lead to a "continual changing of names" for some time, but, to quote from the *Memoranda*, "most of the trouble . . . has arisen from the retention of obsolete nomenclature in . . . text-books and teaching centres. . . . Enforcement of the Rules of Nomenclature may sometimes cause inconvenience, but adherence to the code seems to be the only means of evolving order out of chaos. Eventually . . the student will have to know only one name for each species."

* "A *homonym* is one name for two or more things, a *synonym* more than one name for the same thing."—*Memoranda*, p. 272.

INDEX

(Obsolete or invalid generic or specific names in parenthesis).

THE END

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